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BIONOMICS OF THE PRAWN, *Pandalus kessleri* CZERNIAVSKI

ITSUO KUBO

The prawn, ***Pandalus kessleri*** CZERNIAVSKI, Hokkai-yebi in Japanese name, is a rather large sized prawn inhabiting cold shallow waters, 0.5–10 m[33] in depth of Kurile Islands, Saghalin, the Japan Sea coast of Korea and Sikhota Alin (Russian Territory), Hokkaidô, and the Northern coast of Aomori Prefecture of Japan. Inasmach as it has been undergoing considerably intensitive fishing mostly for material of canning, if the fishery of this prawn is remained in the present state, it may be expected that overfishing takes place before long. Neverthless no investigations carried out from the view points of ecological and fisherybiological studies which afford important fundaments for the fishery, have been done of this resources except some systematic studies worked out by many authors and an account of transportation of the prawn. The writer have had an opportunity to scrutinize some such ecological items as the growth, weight-length relationship, sex-reversal, egg and number of eggs produced, spawning season, larvae, and digestive organs as well as feeding habit of the prawn, and the results obtained are set forth on annexed paragraphs.

Before proceeding any further my warmest thanks are extended to Mr. Ryôsuke KAKUMA, by whom a part of the expence needed for the present investigation is defrayed. My hearty thanks are due to Juzô HORI, Professor of our College, for his kindness extended in various ways, and also to Dr. Toraichirô KINOSHITA and Mr. Yoshimi HIRANO, of the Hokkaidô Fisheries Experimental Station, for their favour of the valuable material on which the present investigation carried out. Acknowledgement is also made to Dr. Yasuo Oshima, Professor of the Tokyo University, in the matters of important literature.

I. MATERIAL AND METHODS

In total 1718 individuals comprising 1535 males, 30.0–114.1mm in body-length without rostrum, and 183 females, 84.0–132.0 mm long were used as the material of the present investigation. The material on which the present study is based has mostly taken monthly from Notsuke Bay, East coast of Hokkaidô as set forth in Table 1, by the Hokkaidô Fisheries Experimental Station during years 1935-'38, mainly in 1936, and has been preserved in formalin.

The measurements of the body-length, used in the present paper, are taken from the post-orbital edge of carapace to the median hind border of the telson.

Table 1. Localities and date, in which the material obtained, amount and range of body-length in mm of the material available. E, ovigerous female; F, females which are in shortly after liberation of eggs; G, females without external eggs; N, Notsuke Bay; No., Number of individuals examined; S, Lake Saroma; T, Tomari-Mura, Kuna-hiri Is. (Southern end of Kurile Islands; *, unknown, 1936 or 1937.)

Localities	Date			Male		Female				
	Year	Month	Day	No	Range of body-length	No E	F	G	Total	Range of body-length
N	1938	1	2–23	91	40.0—108.4	4			4	101.5—122.5
	〃	2	18	40	43.0— 72.0					
	1937	4	18	43	57.2—114.1	7			7	106.3—118.2
	〃	5	29	22	89.9—109.5		4	1	5	106.3—132.0
	1935	6	2	21	47.0— 65.3	4	8	2	14	94.0—122.2
	1937	6	5,15	76	50.0—110.3					
	1936	7	2,15	175	30.3— 68.0					
	1937	7	1,15	103	52.6—103.7			3	3	103.0—118.0
	〃	8	1,14	250	35.0 110.7			1	1	113.1
	〃	9	3,15	78	45.0—100.5	26			26	84.0—114.0
	*	10	1,2,15,17	214	30.0— 95.7	34	3		37	86.0—117.7
Total				1113		75	15	7	97	
S	1937	5	17	36	69.0-- 97.0	19			19	89.5—107.0
	〃	6	2,15	77	71.0—103.0	13	10		23	91.0—110.0
	〃	7	3	41	54.0—106.0			7	7	93.0—113.0
	〃	10	15	30	66.0— 91.5	12			12	99.0—115.0
	〃	12	3	18	65.0— 93.5	25			25	85.0—100.0
Total				202		69	10	7	86	
T	1937	8	6	110	30.0—110.0					
Total				110						
Grand total				1535					183	

II. RESULTS OBTAINED FROM THE PRESENT INVESTIGATION

1. Growth

In order to know the growth of the prawn, an analysis has done on body-length composition of the material collected monthly. The body-length

compositions of the prawns taken from Notsuke Bay and Lake Saroma are given in Tables 2 and 3, and those based on the Notsuke-Bay-material are represented in Fig. 1.

As to the male-material fished from Notsuke Bay in January, 1938, two groups are found to exist. They are 40-80 mm and 80-108.4 mm in range of body-length, and 65-70 mm, and 95-100 mm in mode respectively. In female, the range is 101.5-122.5 mm, but the mode is not defined (Fig. 1, I). The material obtained on Feb. 18, 1937, is represented by male only, the body-length is 43-72 mm in range and 55-60 mm in mode. In the material secured on April 18 of the same year, two groups of male and one group of female are found to exist again as is the case with that in January, 1938. The mode of the body-length in male falls on 65-70 mm and 85-90 mm respectively, and the body-lengths of females vary from 106.3 mm to 118.2 mm (Fig. 1, G).

Table 2. Frequency distribution of body-length of *Pandalus kessleri* taken from the Notsuke Bay. F, females; M, males; R, intersexes; *, on which the samples are collected.

Date * Month Day	Items	Body-length (mm) 30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100	100–105	105–110	110–115	115–120	120–125	125–130	130–135	Total
1 2–23	M			2			4	5	10	7	3	2	14	12	17	13	2						91
	R							1	4	1	1		9	8	11	9	1						45
	F															1	1	1		1			4
2 18	M			1	11	3	12	8	4	1													40
	R																						
	F																						
4 18	M						1	4	9	9	1	1	6	1	4	4	1	2					43
	R						1	4	9	9	1	1	6	1	4	4	1	2					43
	F																1	3	3				7
5 29	M												1	5	7	6	3						22
	R												1	5	7	6	3						22
	F																1	2			1	1	5
6 2–15	M				13	12	7		2	7	15	16	12	9	5	6	2	1					97
	R									1	6	15	12	9	5	6	2	1					57
	F													1		3	3	2	3	2			14
7 1–15	M	19	33	16	9	37	50	31	21	15	7	2	6	14	12	6							278
	R									5	3		5	14	12	6							45
	F															1			2				3
8 1,14	M		30	49	7	1		2	17	38	24	13	18	15	17	15	3	1					250
	R											5	16	15	17	15	3	1					72
	F																	1					1
9 3,15	M				1			1	5	19	18	16	7	3	6	1	1						78
	R										1	3	3	1	6	1	1						16
	F											1	1	3	4	13	3	1					26
10 1–17	M	7	40	50	30	15	10	6	1	1	11	18	17	7	1								214
	R												2	1									3
	F												4	6	14	8	1	2	2				37
Total	M	26	103	118	61	68	84	57	69	97	79	68	81	66	69	51	12	4					1113
	R						1	5	13	16	12	24	54	54	62	47	11	4					303
	F											1	5	10	18	26	10	12	10	3	1	1	97
R/M (%)							1.3	8.7	19.1	16.4	16.6	35.2	66.6	81.8	89.9	92.1	91.7	100	0				

The samples taken on May 29, 1937 consist of males having body-length 89.9–109.5 mm in range, 95–100 mm in mode, and females measuring 106.3–132.0 mm long (Fig. 1, F). With regard to the material collected on June 5 and 15, 1937, three male-groups and two female-ones probably appear to exist. The mode of body-length of each group is 50–55 mm, 80–85 mm, and 90–100 mm in male, 100–105 mm and 115–120 mm in female respectively (Fig. 1, E). Of the material taken on July 1, 2, 15, 1937, also three groups are defined in male. The range and mode of the body-length may be given respectively as follows: 30–50, 50–80, 80–105 mm, and 34–40, 55–60, 90–95 mm (Fig. 1, D). But the females found in the material are only three in number. The range of body-lengths run 103–118 mm. Regarding to the male of the material taken on August 1 and 14, 1937, three populations appear to exist. The mode of the body-length lies on 40–45 mm in the first group, on 70–75 mm in the second one. In the third group the mode is not well defined, but it seems to exist in the neiphbourhood of 95–100 mm. Female is represented by only one individual (Fig. 1, C). On the material fished on September 3 and 15 of the same year, three male groups and one female group probably appear to be present. The first male group consists of only two individuals, but it seems to the writer to be corresponding to the first group of the previous month. The second

Table 3. Frequency distribution of body-length of *Pandalus kessleri*, obtained from the Lake Saroma. F, females; R, intersexes; *, on which the material is gathered.

Date * Month	Day	Items	Body-length (mm) 50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100	100–105	105–110	110–115	115–120	Total
5	17	R				1	7	9	6	7	5	1					36
		F								1	2	10	4	2			19
6	2,15	R					5	17	13	15	11	12	4				77
		F										6	8	6	3		23
7	3	R	1	1			2	3	14	7	5	5	2	1			41
		F									1	3	1	2			7
10	15	R				5	12	2	6	3	2						30
		F										1	3	2	5	1	12
12	3	R				1	5	2	4	3	3						18
		F								5	14	5	1				25
Total		R	1	1		7	31	33	43	35	26	18	6	1			202
		F								6	17	25	17	12	8	1	86

group is well defined, 60–90 mm in range and 70–75 mm in mode of body-length. Although the third one is not well defined inasmuch as the material being rather insufficient in number, it shows range and mode of body length being 90.0–100.5 mm and 95–100 mm respectively. In the female, the body-length ranges from 84 to 114 mm with a mode at 100–105 mm (Fig. 1, B). As to the material obtained on October 2, 15, and 17, 1937 or '38, two male

groups and a female one are recognized. The range and mode of the body-length of each group are as follows respectively giving the mode in brackets: 30-65 mm (40-45 mm), 70-95 mm (80-85 mm) in males, 86.0-117.7 mm (95-100 mm) in females (Fig. 1, A).

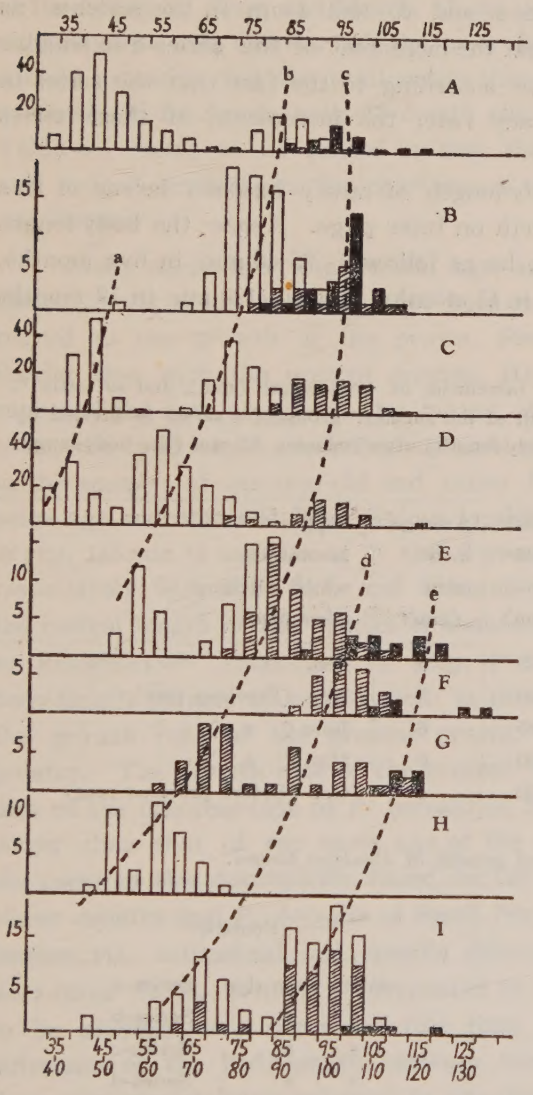

Fig. 1. Body-length composition of *Pandalus kessleri* catched monthly in the Notsuke Bay, and showing progression of body-length modes of 5 age-groups (a-e). A, taken on October 2, 15, 17, 1937 or '38; B, caught on September 3, 15, 1937; C, taken August 1, 14, 1937; D, taken on July 1, 2, 15, 1936 and '37; E, fished on June 5, 15, 1937; F, obtained on May 29, 1937; G, taken on April, 1937; H, caught on February 18, 1937; I, collected on January 2-23, 1938. Abscissa, body-length in mm; ordinate, number of individuals. White, males; hatched, males under sex-reversal; black, females.

Glancing over all the material, five series of population (a-e) are recognizable, and each of the series seems to be different in age (Fig. 1, a-e). The series-a consists of the smallest groups of the July-and August-materials with modal body-length, 35-40 mm and 40-45 mm respectively. The series-b made up of the groups of the months from June to October. The mode of the body-length of these groups is respectively as follows: 50-55 mm, 55-60 mm, 70-75 mm, 70-75 mm, and 80-85 mm. The series-c is composed of the following groups: 55-60 mm (in mode)-group of February, 65-70 mm-group of April, 80-85 mm-group of June, 90-95 mm-group of July, 95-100 mm-group of August, 100-105 mm group of September, and 95-100 mm of October. The series-d consists of 65-70 mm-group of January, 85-90 mm-group of April, 95-100mm-group of May, and 95-100mm-group of June. Finally the series-e is composed of 95-100 mm-group of January, 110-115 mm-group of April, and 115-120 mm-group of June.

The monthly increment of body-length of these series given above shows some extent of variation, viz., that is about 5 mm in the series-a, 8 mm in the series-b, 6 mm in the series-c and -d, and 4 mm in the series-e, as demonstrated in the Table 4. It that the increment of the series-e is smaller than that of other series, may be according to the fact that the series in question is of advanced age. At any rate, the increments of these series average about 6 mm.

On the other hand, the body-length of newly hatched larvae of this prawn measures 6.5 mm as set forth on later page. Hence the body-length of this animal may be supposed to be as follows: 35–40 mm in five months, 65–70 mm in 10 months, 95–100 mm in 13 months, and 115–120 mm in 18 months after hatching (Table 5).

Table 4. The range in mode and the increment of body-length (mm), and so forth. *, doing suspposition, the modal body-length of the smallest group of a series is divided by 6 mm (monthly average increment of body-length) after reducing 6.5 mm (the body-length of newly hatched larvae.

Series	Range in mode of body-length	Period (Number of months)	Total increment (mm)	Average increment (mm)	Supposed * months in which hatching takes place
a	35–40	July-Aug. (1)	5	5	Feb.
b	50–80	June-Oct. (4)	30	8	Nov. (Previous year)
c	55–100	Feb.-Sep. (7)	45	6	June (〃)
d	65–95	Jan.-June (5)	30	6	Mar. (〃)
e	95–115	Jan.-June (5)	20	4	Oct. (Before previous year)

Table 5. Supposed growth of *Pandalus kessleri*.

Months after hatching	Body-length (mm)	Remarks
5	35—40	taken from the Series-a
7	50—55	〃 〃 Series-b
8	55—60	〃 〃 Series-c
10	65—70	〃 〃 Series-d
13	95—100	〃 〃 Series-e
15	95—100	〃 〃 Series-d
16	100—105	〃 〃 Series-c
18	115—120	〃 〃 Series-e

If the supposition made above is true, the parwns which belong to the large sized group appear to elapse 18 months after their hatching, and accordingly the life-span of this prawn is mostly one and half or two years.

The months in which the prawns of each series have hatched are supposed to be as follows: February in the Series-a; November of the previous year in the Series-b; June and March of the previous year in the Series-c and-d respectively; and October of the year before last (Table 4). It should be noticed herewith that the irrationality that the supposed average body-length is samely 95-100 mm in both 13-month olds and 15-month olds (Fig. 1 and Table 5), seems to be caused by that the modes of those maniples are not well defined according to the shortness of the material obtained in September and October.

Many accounts on the growth, age, and length of life of the prawns included to the genus *Pandalus* have been made by many investigators. With regard to the growth of the prawn, *Pandalus borealis*, which reaches to a similar size with the present species, HJORT and RUND[8] have worked and supposed the rate of growth by means of Petersen-method. According to them, the total length (including rostrum) of the species, *P. borealis* is 78 mm in the samples of one-year-old and taken from Oslo, 81 mm in those of the same age and obtained from verious localities of South Norway except Oslo, 92 mm, 115 mm in samples of 2- and 3-years-olds respectively. These become respectively 54.6, 56.7, 64.4, and 80.5 mm in body-length without rostrum as the rostral length of this species is about 30% of the total-length. According to RASMUSSEN[24] [EINASSON[7], P. 153], *P. borealis* of Spitzbergen is 56 mm in body-length (80 mm in total-length) in three-year olds. Comparing to these, the growth rate of the present prawn, *P. kessleri* appears to be much greater. The growth rate of the present one is twice larger compared to that of the one-year-olds of *P. borealis* of South Norway, and is even 6 times larger than that of the same age of the same species of Spitzbergen. For the cause of this discrepancy found on the growth rates between *P. kessleri* of our country and *P. barealis* of South Norway and Spitzbergen, a couple of factors viz., latitudinal and specific differences, are at least taken into consideration. It is, however, interprated to the writer that the former seems to be playing more important rôle than the other one, since the specific difference of the body-length between these two species is to be little as these two species being subequal in size limit.

The growth-curve of *Pandalus nipponensis* YOKOYA has given by carapacial length by TAMURA[30] on his Fig. 3. According to the figure, the body-length* of the 1-year-olds is 70 mm, and thoes of 2-, 3-, and 4-year-olds are 120 mm, 152 mm, and 152 mm respectively. These values are rather small

*, Converted from the carapacial length given by Tamura. In this species, the carapace-length is as a rule about a quarter of the body-length.

in comparision to the supposed body-lengths of the present species, *P. kessleri*.

TAMURA (loc. cit.) mentions that the longevity is as much as 4 years in majority of *P. nipponensis*. The length of life of *P. borealis* of South Norway appears, according to HJORT and his collaborator (op. cit.), to be 3 years. Of the same species, RASMUSSEN (op. cit.) approves 5 years as its life-span. In comparision to these, the life span supposed as 2 yesrs for *P. kessleri* as set forth already seems to be rather short. For such species as *P. kessleri* being an inhabitant of rather cold waters, it may be, however, in propriety taking the following fact into consideration, viz., the life span of natant forms of shrimps and prawns inhabiting warm waters is commonly one or a little more than one year. The average life-span of the American species, *Penaeus setiferus*,[35] *Crago nigricauda* and *C. franciscorum*,[9] *Penaeus orientalis*[26,27,41] inhabiting Yellow Sea. and such Japanese forms given below: *Trachypenaeus curvirostris*[38], *Metapenaeus affinis*[1, 22], *Acetes japonicus*, *Leander paucidens*[10], *Leander serrifer*[11], *Paratya compressa improvisa*[29], and *Palaemon nipponensis*[16, 17] has been deduced to be one year by many investigators.

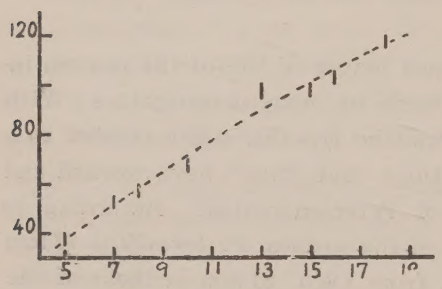

Fig. 2. Growth carve of *Pandalus kessleri* taken from size analys's basing on monthly samples commercially fished from the Notsuke Bay. Abscissa, months after hatching; ordinate, body-length in mm.

(2) Weight-Length Relationship

In order to know the relationship between body-length and body-weight, 38 males, 41 sex-reversing individuals, and 9 females were weighed and measured. All of the specimens caught from the Notsuke Bay on January 2, July 1, September 3, and October 15. The body-length of these samples ranges 30.0–95.00 mm in males, 71.0–107.0 mm in sex-reversing individuals, and 98.0–113.0 mm in females. The range of body-weight of them runs from 0.28–10.40 g, 4.20–16.35 g, and 12.05–19.90 g, respectively as listed in the Table 6.

The relationship in question is delineated in the Fig. 3. Seasonal difference is not found to exist. The relation between body-weight (W) and body-length (L) may be expressed by the next equation: $W = 0.00000636\ L^{3.147}$.

The regression equation expressing the relationship of *Penaeus japonicus*

Table 6. The date on which the collection has been done, number of individuals (No), and ranges of length (mm) and weight (g) of body of the specimens used for the investigation of weight-length relationship of *P. kessleri*.

Date		Male			Sex-reversing			Female		
Month	Day	No.	Length	Weight	No.	Length	Weight	No.	Length	Weight
1	2	1	74.0	4.52	19	87.0–103.0	7.40–13.35	1	110.0	17.58
7	11	4	59.0–56.0	2.30–3.40	14	71.0–100.0	4.20–13.20			
9	3	7	69.0–95.0	3.80–10.40	8	78.0–107.0	6.00–16.35	8	98.0–113.0	12.05–19.90
10	15	26	30.0–50.0	0.28–2.55						
Total		38			41			9		

of the Inland Sea of Japan has been given by KADIYAMA[12] as $W = 0.013\ L^{3.0}$. The equation given by YAMAMOTO[37] for the same species of the Lake Hamana is $W = 0.0071\ L^{3.0093}$, and that given by INOUYE[11] for *Leander serrifer* is $W = 0.00000886^{3.257}$.

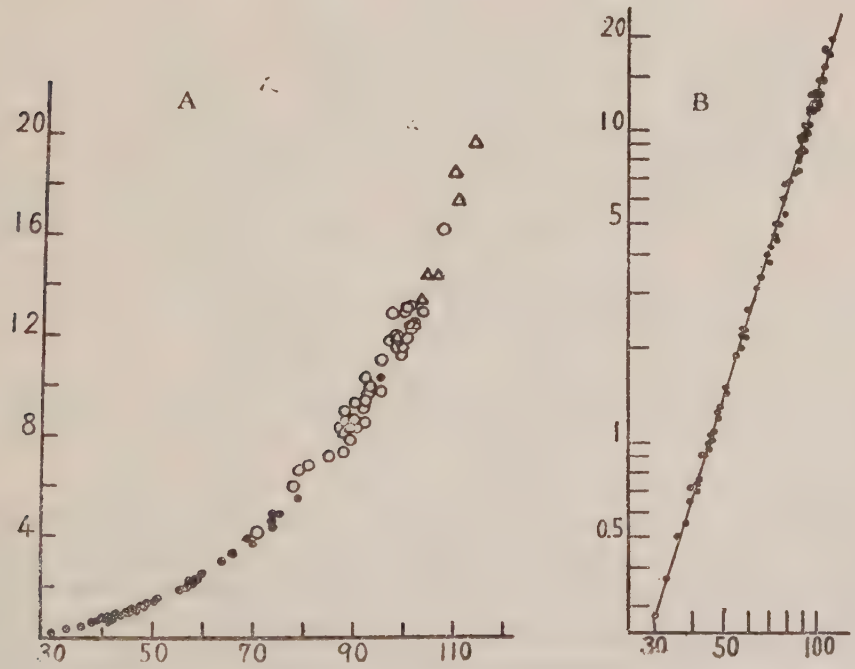

Fig. 3. Weight-length relationship of *Pandalus kessleri*. Abscissa, body-length in mm; ordinate, body-weight in g. Black circles, male; white ones, intersexes; triangles, ovigerous females removed all the external eggs.

From the above, we have been revealed that the power of the re-

gression equstion of such macrurans, at least, is close to 3. Thus the SPENCER's cube law [KEYS[13]] may be applicable for such macrurous decapod crustaceans as is the case with many fishes.

(3) Sex-Reversal

Basing on the transformation of secondary sexual characters found on the endopodites of both the first and second pleopods and the anatomical observations carried out on the gonads, it is shown as noted later that the prawn *P. kessleri* is a protandorous hermaphrodite as is the case with such many prawns included within the genus *Pandalus* as *P. danae*[35], *P. borealis*[8,24] *P. montagui*[19,36] and *P. nipponensis*[30]. Of these matters, details have been given below at first, and some considerations regarding to the relations found between body-length and sex, as well as between age and sex will be given here.

The change of secondary sexual characters found on the endopodites of the first and second pleopods: The endopodites of the first abdominal appendages are leaf-shaped in both male and female. But each the endopodite of male is provided with an appendix interna at its inner tip as is the case with many species[14] belonging to the genera: *Paratya* and *Caridina*, of Atiydae, and that of female is without appendix interna and has a tongue-like protuberance at tip (Fig. 4, G). This appendage appears to become complete in configuration when the animal measures about 47.5 mm in body-length (Fig. 4, C). The appendix interna gradually decreases its length in accordance with growth. It is 0.3 times as long as the endopodite in the young 30.3 mm long, while that is 0.11 times the length of the endopodite in both the specimens 42.0 mm and 47.5 mm in body-length (Fig. 4, B and C). After that the endopodite becomes complete, however, the appendix interna begins to shrink, and conversely the tip of the endopodite institutes to develop longer. Remarkably enough, two phases, at least, are found to exist in the process of shrink of the appendix interna (Fig. 4, D and E).

With regard to the second pleopods, the endopodite is provided with appendix interna and appendix masculina in male, and with the former only in female as is the case with many other prawns and shrimps. The appendix masculina appears at first at the time the prawn reaches to a length of about 30 mm. The appendix masculina of a specimen, 30.3 mm long, obtained on July 15 from the Notsuke Bay is still bud-like in shape, about a quarter as long as the appendix interna (Fig. 4, H). The appendix masculina grows as long as half of the appendix interna when the animal attains a length of 35 mm in body-length, and it measures twice the length of the other appendage and

becomes provided with many bristles on the apex and other parts of the organ (Fig. 4, J). The appendage in question becomes more longer, lengthens to 2.3 times the length of the appendix interna in a specimen 54 mm long. At the time the prawn reaches to a length of 60 mm in body-length, the app ndix masculina appears to develope almost completely as being 2.7 times as long as the other appendix and more increased in number of the bristles grown on itself (Fig. 4, L). In a more larger specimen such as 77.5

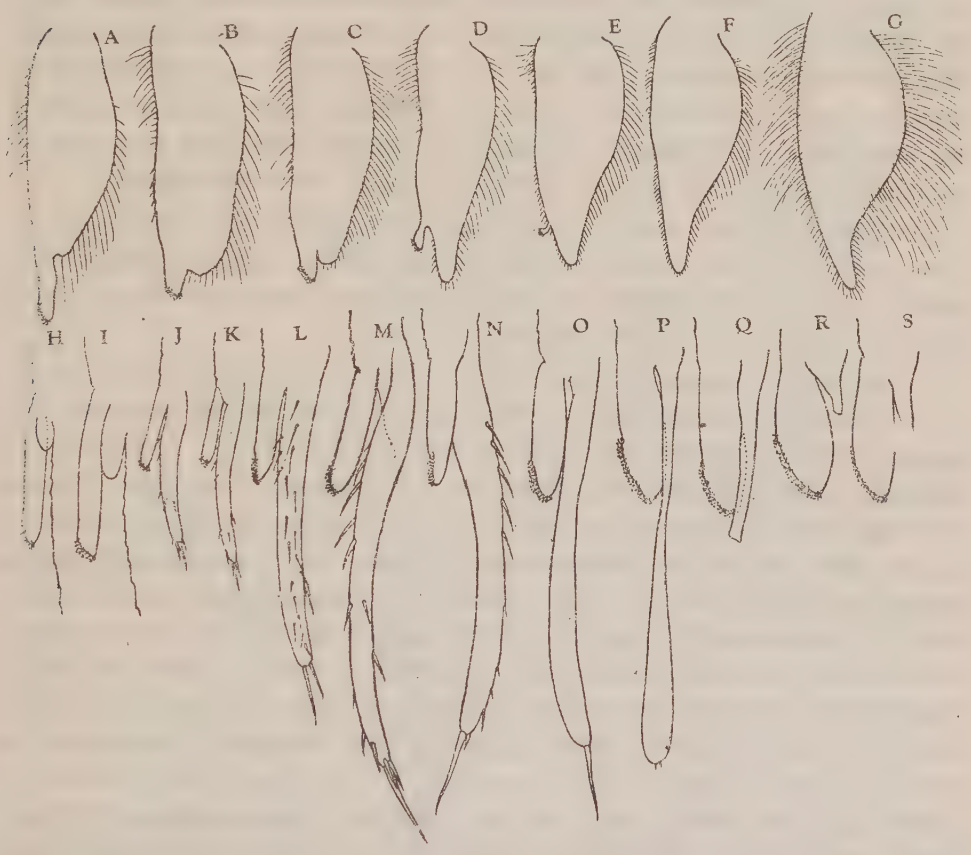

Fig. 4. Showing transformation of the endopodite of the first pleopod of male (*A–F*), the same endopodite of ovigerous female (*G*), and the appendixes interna and masculina of the second pleopods (*H–S*) of *Pandalus kessleri*. *A*, 30.3 mm in body-length, taken on July 15, ×50; *B*, 42 mm, July 2, ×25; *C*, 47mm, ×20; *D*, 90mm, Jan. 15, ×7.5; *E*, 101mm, June 15, ×7.5; *F*, 101 mm, July 1, this specimen with appendix masculina undergone great degeneration, ×7.5; *G*, 110.5 mm, ovigerosus female, ×7.5; *H*, the same as in *A*; *I*, 35mm, August 14, ×50; *J*, 45 mm, August 14, ×15; *K*, 54 mm, July 3, ×15; *L*, 60 mm, August 14, ×15; *M*, 77.5 mm, August 6, ×15; *N*, 77.5 mm, June 15, ×15; *O*, 87.5 mm June 15, ×15; *P*, 96.5 mm, June 15, ×15; *Q*, 98 mm, June 15, ×15; *R*, 102 mm, July 3, ×15; *S*, 88 mm, June 15, specimen caught soon after ecdysis, ×15. *A–J*, *L*, taken from the Notsuke Bay; *K*, *N– Q*, taken from the Lake Saroma; *M*, caught from Tomari-mura, Kunashiri Island.

mm long, this organ more lengthens and measures about 3.2 times as long as the appendix interna, but begin to demonstrate a slight degeneration in feature and the bristles found on the organ decrease in number (Fig. 4, M, N). The appendix masculina undergone strong degeneration is club-shaped in feature as it thins intensively at about one-third of its length, the bristles found to grow on it almost fall off (Fig. 4, O, *P*). Then it becomes apt to break off from the thined portion (Fig. 4, Q). Many instances having the appendix interna broken off in such state mentioned above are found to exist. The appendix masculina undergone more strong degeneration gets rudimentary and finally vanishes at all. But in contrast to this, the appendix interna begins to show a tendency to get larger, and finally it becomes to display a feminine feature. It should be mentioned herewith that four steps are recognized at least in the process of the shrinkage of the male organ.

From the facts given above, it is easyly infered that several ecdyses take place during the process of sex-reversal of this prawn. Lastly it is specially noticed that no specimens having female characters are found among those less than 55 mm in body-length.

Anatomical aspect of gonads: The gonad of a male, 62 mm long, secured from the Notsuke Bay on October 1, is H-shaped and provided with numerous cross wrinkles on its dorsal surface (Fig. 5, A). A pair of vas deferenses leads from posterior about a third of the sides of the gonad. The vas deferens measures about 10 mm in length, has a loop near its base, is attached to the side wall of the sperm-reservoir in distal end, and gradually widens toward the sperm-reservoir. The reservoir is spindle-shaped, about 1.5 mm long. In a specimen, 105 mm long, which appears to be in an early stage of sex-reversal inasmuch as bearing an appendix masculina undergone slight degeneration, and appears to have had at least twice the role of a male in two breeding seasons, the gonad is found greatly plumped in comparision to that of a male being before sex-reversal, and is about spindle-shaped in outline in dorsal aspect (Fig. 5, M, N). The vas deferens springs off from about posterior one-third of the gonad as noted above, and is convoluted rather complicately near its base. The shape of the sperm-reservoir closely resembles that of the male given above, the size is found more developed with a length of about 2.5 mm (Fig. 5, B). It should be especially noticed here that the gonad is uniformly filled up with unripe eggs polygonal in shape and 0.8–1.0 mm in the largest diameter. In another specimen which is 87.5 mm long, caught from the same bay on July 15, provided with vestigial appendix masculina, and seems to have one brood after its development, the gonad has been seen to be samely filled, as in that of the aforementioned

prawn, 105 mm long, with unripe eggs, 0.4–0.8 mm in the largest diameter (Fig. 5, E). Moreover it is very interesting to note that an ovigerous female, 104 mm long, fished from the Lake Saroma on May 17, has its ovary afforded with a pair of vas deferences in addition to the oviducts (Fig. 5, C). This vas deferens, however, more or less exhibits a trend of shrinkage comparing with that of the aforementioned male specimen which measures 105 mm long and is already put on the course of sex-reversal.

Through the matters writen above, it may be concluded as follows. The gonad of even such individuals which are in the process of sex-reversal

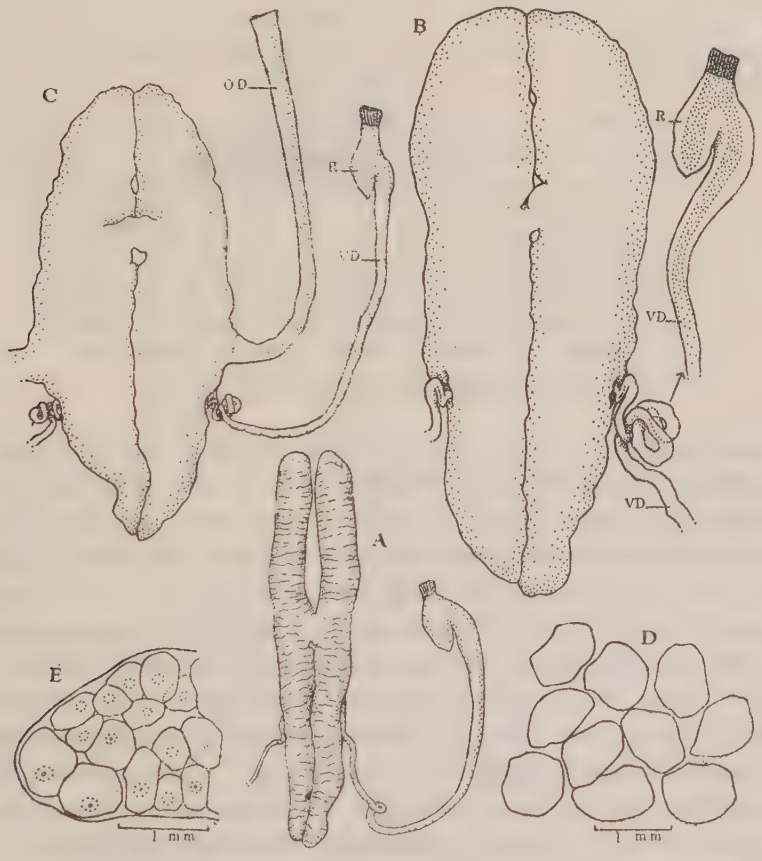

Fig. 5. The gonads of *Pandalus kessleri*. *A*, testis dissected out from a male, 62mm long, secured on October 1, from Notsuke Bay, ×5.5; *B*, testis of a male, 105 mm long, with the appendix masculina slightly degenerated, taken on January 20–22, from Notsuke Bay, ×4; *C*, ovary of an ovigerous female, 104 mm long, obtained on May 17, from the Lake Saroma, ×4; *D*, eggs found in the testis of the male of *B*; *E*, eggs found in the testis of a male, 87.5 mm in body-length, with vestigially remained appendix masculina, collected on July 15, from Notsuke Bay; *OD*, oviduct; *R*, sperm-reservoir; *VD*, vas deferens.

from male to female and still are having male external characteristics, has been changed completely into ovary. The vas deferens is still remained in the ovary of ovigerous female reversed from male. Accordingly it is that the ovary of such female is furnished with vas deferenses in addition to oviducts as already reported by BERKELEY[3] on *Pandalus danae.*

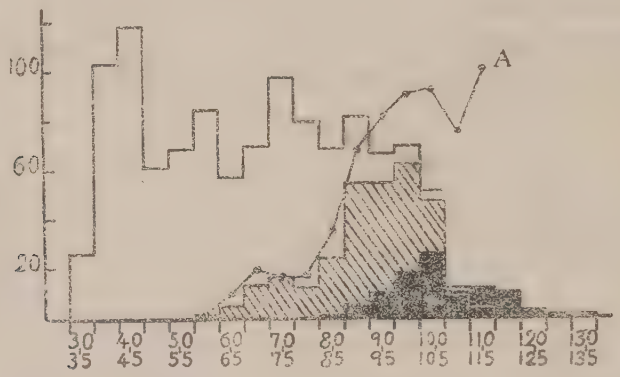

Fig. 6. Body-length frequency distribution of the whole samples examined and the percentages of males to ones being under sex-reversal (A). Abscissa, body-length in mm; ordinate, number of individuals and percentage. White, male; hatched, male being under sex-reversal; black, female.

Sex-reversal in relation to body-length and age: In the prawn of this species, the body-length of male is less than 55 mm, and the sex reverses when body-length measures 55–115 mm as mentioned already (Figs. 1 and 6). Females are more than 80 mm in body-length, in which the mode is 100–105 mm. Two groups, large and small, of the intersexes, seem to exist. Each of the group shows a mode of 65–70 mm and 95–100 mm respectively in body-length. The frequencies of the sex-reversed individuals in each 5 mm length group are below 20% in the small sized group and are above 35% to 100% in the largesized group (Fig. 6). Therefore the sex-change of this prawn largely appears to take place when the prawn measures about 100 mm in body-length, and all the animals completely reverse to female when they are about 115 mm long. Judging from the following two facts——(1) the appendix masculina developes completely when the prawn reaches a length of 50–55 mm, and (2) the growth-rate deduced from size-analysis as to the samples taken monthly, —— the small-sized group seems to be a group had brood once, and the large-sized one had twice. The relation between the sex-reversal and the age of this prawn may be given as follows: some ones undergo sex-reversal at 7 or 8 months after their development, but most ones

at 12 months in the small-sized group and at 13–17 months in the large-sized one, and then all ones change their sex into female at about 18 months after their hatching.

In the prawn, *P. kessleri*, the minimum size entering into sex-reversal is 55 mm long as mentioned already. This minimum size nearly accords with that of *P. danae*[33], *P. montagui*[36] (EINARSSON, p. 167)[7], and *P. borealis*[8] as it is 60 mm, 55–60 mm, and 70 mm respectively. But it differs greatly compared to that of Spitzbergen's *P. borealis* and that of the Japanese deep-sea form, *P. nipponensis*. According to RASMUSSEN[24] (EINARSSON, p. 153, loc. cit.), sex-reversal of the Spitzbergen's *P. borealis* has been known to occur in the five-year-olds measuring 110 mm long. As to *P. nipponensis* TAMURA[30] reports that the sex reverses during a period from 2 to 3 years after hatching and the body-length at the time of sex-reversal is 120–140 mm. The body-length of the intersexes ranges 60–100 mm in *P. danae*, 70–77 mm in *P. borealis*[8], But that of the present prawn, *P. kessleri* largely agrees to that of the former species as it runs 55–115 mm.

The minimum size of appearance of the appendix masculina is 30 mm in *P. kessleri*, and 35 mm in *P. danae* as reported by BERKELEY. Thus these two species also may be said to be similar in this respect.

(4) Egg and Number of Eggs Produced

Size and shape of egg: The ova are large in size and elliptical in shape as is the case with the most species belonging to the genus *Pandalus* and other genera near the genus *Pandalus*. The pre-eyed eggs taken from a specimen, 117.5 mm long, commercially catched from Notsuke Bay on January 20–22, measure 2.2–2.3 mm in longer diameter, 1.5–1.8 mm in shorter one. The eyed-eggs obtained from three specimens, 94–97 mm in body-length, taken from the same bay on May 17, are 2.4–2.7 mm in longer diameter, 1.7–1.9 mm in shorter one.

Number of eggs produced: The number of eggs of each individual is counted one by one. The eggs attached beneath abdomen of each individual are rather small in number, but show considerable variation in number. The number counted in 38 specimens 84.0–118.2 mm long, ranges from 191 to 496. The relationship between number of

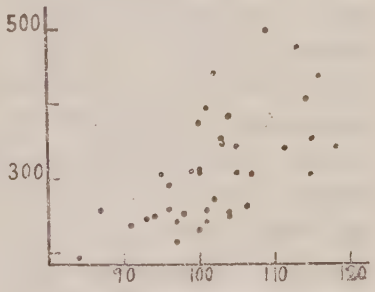

Fig. 7. Graph showing relationship between the number of eggs laid and the body-length (abscissa, mm) of the ovigerous females on which the counts of the eggs were made.

laid eggs and body-length appears to be positively nearly linear in trend (Fig. 7). The prawns measuring ca. 90 mm, ca. 100 mm, ca. 110 mm, and ca. 120 mm in body-length, bear 170–350, 200-400, 250–500, and 350–550 eggs respectively. In this connection it should be mentioned that the most diminutive ovigerous female examined measures 84 mm in body-length.

(5) Breeding Season

So far as the present investigation goes, egg-bearing females are found in all other months except for those three months: February, July, and August (Table, 1). More amount of material, however, would be required to ascertain whether ovigerous females are truly absent in February or not. Remarkably enough, no ovigerous female is collected in July and August in spite of a considerable amount of material gathered from the Notsuke Bay as well as the Lake Saroma. Judging from the facts set forth above, the interval in which the berried prawns occur, appears to be long, at least it runs from September to June of the next year. Moreover, young prawns indicating 30–40 mm long seem to be found to occur throughout whole the year inasmuch as a considerable amount of such young prawns are found catched in the material taken from the Notsuke Bay and its adjacent waters in January, February, July, August, and October. Basing on the matter just aforementioned, the breeding season also seems to be covering a long period. However it appears to the writer that there is two, spring-and autumn-peaks of spawning of this prawn, and the breeding activity is more vigorous in the spring than in the autumn judging from the frequency distribution of the ovigerous females given in the Table 1.

The interval from the oviposition to the hatching is now unknown. But there is an instance available for the basis to think that the incubation interval of an individual may be about one or two months. The instance is of three females taken on October 17 from the Notsuke Bay. These three appear to be captured shortly after liberation of their external eggs attached on the pleopods. Then if the fact that the persent prawn does not have external eggs during those two summer months, namely July and August, as set forth already, is true, the three females in question may be referred to have had their external eggs during an interval about from the middle of August to that of September, and it comes to that the incubation-interval of the prawn is approximately one or two months.

As a reference, it may be mentioned herewith that *Pandalus nipponensis*, a deep-sea form, according ro TAMURA (op. cit.), requires nearly an year for incubation viz., the prawn breeds during from February to May and the

larvae leave from their mother prawns during the period from February to April of the next year.

(6) Larvae

Nothing has been known of the larvae of the present prawn. The writer has examined a number of the larvae taken out from eggs which are still adhering on pleopods of their mother prawns and having chitinous egg-case broken already and loosely embracing the larvae. The larvae are found to be in a zoea-stage, measure a length of 6.3-6.5 mm in body-length. The abdomen is not found stretched backward yet, and the larvae are folded over on themselves so that the pleon is flexed under the cephalo-thorax and the telson curves up over head with distal end reaching to psterior edge of the eyes.

A morphological description may be given as follows. Carapace 0.37 times as long as body. Rostrum very short, not yet free, hardly observable in ventral aspect inasmuch as it recurves towards ventral side of the cephalo-thorax (Fig. 8, B, r). Each segment of pleon not defined yet. Telson inverted heart-shaped, 0.7–0.8 times as wide as long and about a seventh the length of body furnished with several setae on post-lateral rim of each right and left lobes (Fig. 8, A). Eyes large, compound, the longer diameter of cornea about a third as long as carapace. Antennule with a peduncle made up of three segments, and inner and outer flagella attached on distal margin of the third peduncular joint. These flagella very short, unsegmented (Fig. 8, B and C, a). Antenna found well developed already, the scale appears nearly achieved, but the flagella not yet segmented (Fig. 8, C, b). Mandible and maxillulae very rudimentary, simply bud-like in shape (Fig. 8, D, c and d). Maxillae somewhat longer and larger than maxillulae, provided with exopodite (Fig. 8, D, e). All maxillipeds with exopodite. First maxilliped about twice longer than maxilla. Second and third ones subequal in length, about 1.7 times as long as first maxilliped (Fig. 8, D, f-h). Pereiopods are not separated and enclosed in a large sac bulbiform in shape (Fig. 8, D, i). Pleopods from first to fifth subequal in size and length, composed of both endopodite and exopodite with rather pointed tip (Fig. 8 E, j-n). Sixth pleopods not yet separated from telson, and their rudiments are found to exist on each basal lateral side (Fig. 8, A).

Throughout the descriptions made above, striking characteristics are given as follows, (1) the telson is inverted heart-shaped with round sides and has rather shallow posterior notch, (2) the rostrum is still not free, (3) of all the appendages, the tips of both the inner and outer flagella and distal

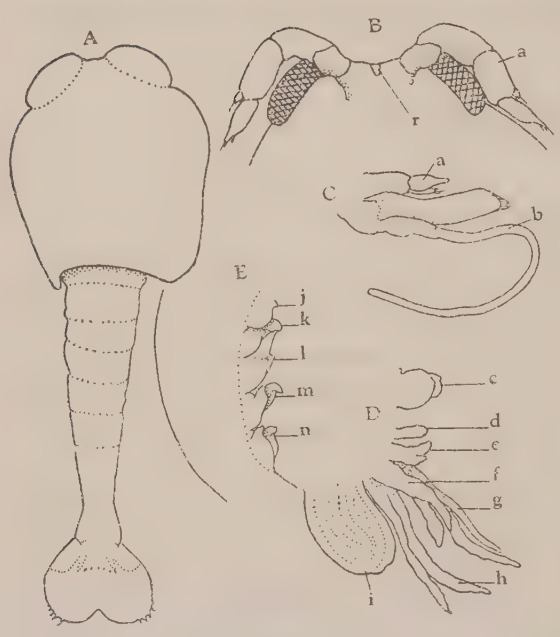

Fig. 8. A larva of *Panda'us kessleri*. *A*, a dorsal aspect of a larva taken out from a egg being just before hatching, with abdomen artificially stretched, ×12.5; *B*, a ventral view of anterior end of the head, ×17.5; *C*, antennule and antenna, ×14; *D*, lateral aspect of appendages of the cephalothorax, ×14; *E*, lateral aspect of the pleon, ×14; *a*, antennule; *b*, antenna; *c*, mandible; *d*, maxillule: *e*, maxilla; *f–h*, maxillipeds; from first to third maxilliped; *i*, pereiopods enclosed within a bulbiform sac; *j–n*, pleopods from first to fifth.

margin of the scales of the antennae only have rudimentary setae, and (4) all the ambulatory legs are found not yet separated from each other and are enveloped within a large bulbiform sac.

If the newly-hatched larvae of *P. kessleri* have set free with such morphological traits noted above, the larvae of this species may be said that they hatch out in a stage, at least, younger than those of other species belonging to the same genus, *Pandalus*, to which the present species is included, and other genera allied to *Pandalus*.

It has been set forth by LEBOUR[18] that the newly-hatched larvae of the prawns belonging to the genus *Pandalus* are referable to two types according to the aspect of the pereiopods and the antennal scales, and the larvae of *P. borealis* show an intermediate form between these two types. The first type is characterized by that the pereiopods are rudimentary and the antennal scales are segmented. *Pandalus montagui*, *P. bonneri* and *P. propinquus* are embraced within this type. On the other hand, the second type is marked by that the pereiopods are functional already, and the antennal scales are not segmented. *P. stenolepis*, *P. hypsinotus*, *P. danae* as well as *P. platyceros* belongs to this type. Whilst the larvae of the present species have such characteristics given above. Wherefore they belong to neither of the two types, and they come to an intermediate form as is the case with *P. borealis*.

(7) Digestive organs and food of the prawn

(a) Digestive organs.

The digestive system is consists of mouth-parts, alimentary canal, and digestive diverticula.

Among the organs composing the mouth-parts, the organ having direct relevance to digestion is mandible. The mandible is common in shape with both incisor and molar processes as well as endopodite. The incisor process is armed with several irregular teeth along cutting edge (Fig. 9, A). The endopodite of the mandible comprises three joints and the basal joint is considerably expanded like a plate (Fig. 9, B).

The stomach is divided into two anterior or cardiac and posterior or pyloric chambers. The cardiac chamber is large, occupies the major part of the stomach, but the other one very small in size. Remarkably enough, such stomodaeal sclerites as cardiac, pterocardiac, urocardiac, zygocardiac and prepyloric ossicles which are ordinarily found on the stomach of *Sergestes*

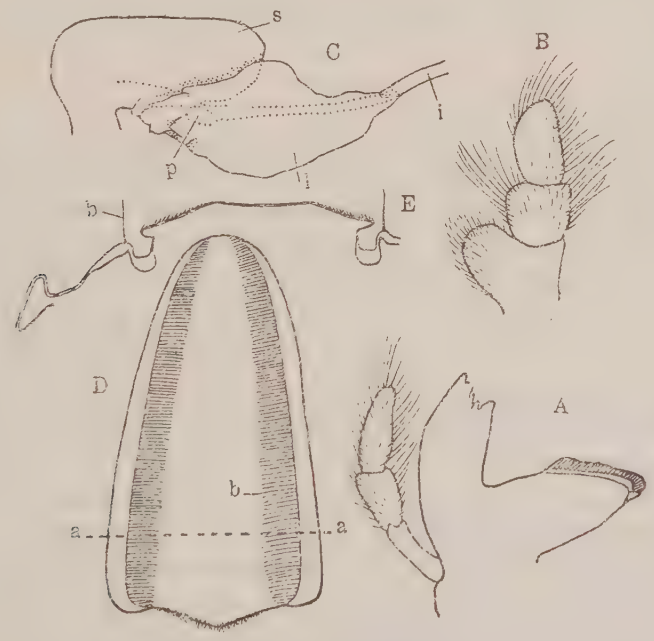

Fig. 9. Digestive organs of *Pandalus kessleri*. *A*, lateral aspect of mandible of a male, 105 mm long, ×6.6; *B*, endopodite of mandible, ×6.6; *C*, stomach, liver (mid-gut) and intestine, ×1.8; *D*, inner aspect of basal plate of the stomach of a male, 87.5 mm long, ×11.6; *E*, cross section at a–a of the basal plate of *D*, ×16.8; b, bristle of the basal plate; i, intestine; l, liver (digestive diverticula); p, pyloric chamber; s, cardiac chamber.

Penaeids, *Stenopus hispidus, Cambaroides japonicus, Cambarus clarkii, Nephrops japonicus, Nephropsis stewarti,* etc., are not developed at all. But a basal plate and a pair of pyloric plates are found to exist as given later.

The cardiac chamber is provided with a basal plate. This plate lies on posterior about half of the floor of the chamber, is tonguelike diminishing anteriorly in width. rounded on anterior border, obtusely angulated on posterior rim with rather thickly set minute hairs, and furnished with long hair-like setae about 355 microns long, arranged in a line along inner lateral sides (Fig. 9, D and E, b). The pyloric chamber is attached to the post-ventral wall of the cardiac one. The relative size against the cardiac chamber is much smaller than the case of Penaeids[15]. The chamber has a pair of pyloric plates (Fig. 9, C, p). These plates are suboval in shape, occupy the greater parts of the chamber.

The mid-gut or digestive diverticula is well developed forming a spindle-shaped mass occupying nearly the whole available lateral and ventral thoracic cavities (Fig. 9, C, l).

The hind-gut is a merely tubular organ runing straightly backwards (Fig. 9, C, i).

(b) Food of the prawn

In order to know the feeding-habit of the present animal, a stomach-content analysis is carried out dealing with 241 specimens taken during such months, January to September from the Notsuke Bay. The result obtained is given in Tables 7 and 8 and may be comdensed up into the followig foure items: (1) such animal-foods as small-sized crustaceans and annelids are overwhelmingly eaten besides such vegetable-foods as diatoms, sea-weeds, eel-grass (*Zostera*), as well as detritus and sands, (2) no evidence of selection for animal-foods is found (It seems that *P. kessleri* is chiefly living on small animals occuring from season to season on its natural environment), (3) shrimps, mysis, and amphipods have been ingested by an overwhelming majority in the months, July to September, (4) frequency percentages of the individuals having empty stomach are higher in the material obtained in winter season than those in the material gathered in other seasons.

Further, details of this subject are given as follows. In the January-material, various kinds of animals are found ingested as the food of this prawn but none of them is eaten especially abundantly. For the April-material, a characteristic is that diatoms are eat in much quantity. As to the July- and September-materials, shrimps and mysis are detected as the major constituents of the food of the prawn in question. Of 47 specimens of the July-material, 11 specimens are found to eat *Pandalopsis mitsukurii*

Table 7. Date of collection, total number of specimens used (A) for the stomach content analysis, as well as number of prawns having empty stomach (B) and its percentages of *Pandalus kessleri* taken from Notsuke Bay.

Year	Date Month	Day	A	B	B/A × 100
1937	4	18	18	6	33.33
〃	7	1	58	11	18.96
〃	8	1	60	23	38.33
〃	9	3	51	17	33.33
1938	1	2	30	20	66.66
〃	1	20–22	24	21	87.50
Total			241	98	40.66

Table 8. Stomach contents of *Pandalus kessleri* collected monthly from Notsuke Bay.

January	a part of fish skeleton; fish scales (cycloid, 3–4mm in diameter); digested amimal body-parts; semidigested annelids; bristles of an annelid; oil-globule-like substance; a part of cheliped of Amphipoda; considerably digested crustacean body-parts with numberless oil-globules; many fragments of bristles appearing to be those of a certain crustacea; eggs of *Pandalus kessleri*; detritus and sands.
April	considerably digested animal body (annelid?); annelid; bristles of annelid; a fragment of sea-weed, about 12mm lodg; large quantity of diatoms; detritus and sand.
July	*Pandalopsis mitsukurii*; mysis (*Stilomysis camtschaticus* Marukawa?) considerably digested shrimps and mysis; a fragment of eel-grass (Zostera), ca. 4cm long; hair-like alga; spindle-shaped diatoms, greenish in colour; detritus and sands.
August	considerably digested amphipod; sands.
September	*Pandalopsis mitsukurii* and its eggs; a mysis which seems to be identifyable to *Stilomysis camtschaticus*; considerably digested annelid-body; small snails; monaxon type spicules of sponge; diatoms; sands.

Rathbun 10 specimens are found bearing semidigested shrimps (identification is impossible) in their stomach, 10 specimens are found taken a lot of a mysis probably referable to *Stilomysis camtschaticus* Marukawa. and 18 ones are found containing mysis undergone considerable digestion within their stomach. Besides these it should be noticed herewith that six specimens among those 47 ones are found eat a considerable quantity of a species of diatom which is depressed spindle-shaped in feature, somewhat greenish in colour, and appears to be forming a colony so that countless of it are found enclosed in a kind of mucous substance when taken out from the stomach of the prawn. In the

August-material, amphipods are found eaten in most cases. In the September-material, a mysis (*S. camtschaticus*?) and *Pandalopsis mitsukurii* are found mostly eaten as is the case with the July-material. Namely in 13 specimens, out of 34 specimens dalt with, mysis are found eaten, in 9 ones, *P. mitsukurii* are found ingested and also in 9 ones, shrimps already digested in considerable degree are found eat. It is worthy of mentioning that, in this September material, numberless sponge-spicules of monaxon type are found to be eaten in two specimens, and three small anails are seen to be taken in a specimen.

In addition to these, muds and sands are almost always found taken, however, it appears to be that they are not taken positively and seems to be merely ingested by chance together with other things available for their food. judging from their quantity found within the stomach.

The frequency percentages of prawns havig empty stomach vary from 18.96 to 38.33 in months from April to September, and the lowest percentage falls on July. Remarkably high percentages are found on January-materials fished in the Notsuke Bay. The percentages of the materials caught on January 2 and 20–22 are 66.66 and 87.50 respectively.

Conclusively it may be mentioned that the prawns in question are evidently polyphagous because they are very torelant in choice of their food as described above, although they appear to be chiefly living on such animals as small crustaceans, annelids. Moreover, it may be guessed that this prawn is living on foods softer than those taken by, at least, Penaeids and those prawns belonging to the annexed genera: *Stenopus*, *Nephropus*, *Nephropsis*, *Cambarus*, and *Cambaroides*, inasmuch as the present prawn is not at all provided with such stomodaeal ossifications necessary for mastication of hard foods in gested as mentioned above. Feeding activity of this prawan seems to be more vigorous in warmer seasons than in colder ones, since the frequency percentages of the prawns with empty stomach are, as given above, higher in winter season than in warmer one.

III. CONCLUSIVE

(1) Infered average increment of body-length is 6 mm par month basing on size-analysis with regard to samples commercially catched monthly from the Notsuke Bay.

(2) The growth-rate deduced by size-analysis is as follows: 35-40 mm, 65–70 mm, 95–100 mm, and 115–120 mm in body-length during 5, 10, 13, and 18 months after hatching respectively.

(3) The life-span of this prawn is guessed to be one and half or 2 years.

(4) The larvae taken out from such eggs just before hatching measure 6.3–6.5 mm. in body-length.

(5) These larvae are in a post-zoea stage. The rostrum and all the pereiopods are not yet free, and the latter are enclosed in a bulbiform sac. The antennal scale assumes an adult form, and is found not segmented. No setae are found to set on any other bodily parts except the telson, tip of both the inner and outer flagella of the antennules and anterior border of the antennal scales.

(6) The regression formula representing the relationship between body-weight (W) and body-length (L) is as follows: $W=0.00000636\ L^{3.147}$.

(7) Salient secondary sexual differences are found to exist on the endopodites of the first and second pleopods. The appendix interna of the endopodites of the first pleopods present in male, but absent in female. The endopodites of the second pleopods are provided with both the appendix interna and the appendix masculina in male, but the former only in female.

(8) The endopodites of the first pleopods become complete when the prawn measures about 47.5 mm long.

(9) The appendix masculina firstly appears at the time the animal reaches to a body-length of about 30 mm, and the organ achives its form when the animal measures 50–55 mm long.

(10) The present prawn is a protandorous hermaphrodite, and the whole examined specimens smaller than 55 mm long are found to be male.

(11) The sex-reversal takes place during 55–115 mm in body-length. Of the intersexes, two large- and small-sized groups are found to exist. The groups are of 95–100 mm and 70–75 mm in mode of body-length respectively. But the sex of the majority of the prawns reverses when the animal attains lengths of the large-sized group. It appears to be that the prawns belonging to the small-sized group are those spawned once, and those of the large-sized group are those bred twice.

(12) All the prawns appear to undergo sex-reversal during an interval from 7 or 8 to about 18 months after hatching. Most prawns of the small-sized group seen to be at the age of about 12 months, and those included into the large-sized one at the age of 13–17 months.

(13) The gonad is found filled already with unripe eggs even in such individuals undergone only slight degeneration of appendix masculina.

(14) The ovary of ovigerous females is found furnished with a pair of vas deferenses besides a pair of oviducts.

(15) Ovigerous females are found during a period from September to June

of the next year.

(16) The spawning season has two peaks, one peak lies on spring-months probably from April to May, and the other on autumn-months probably from September to October, and the latter seems to be more vigorous in breeding activity than the former.

(17) The smallest ovigerous female measures 84 mm in body-length.

(18) The eggs are oval in shape. The pre-eyed eggs taken from a female, 117.5 mm long, are 2.2–2.3 mm in longer diameter and 1.5–1.8 mm in shorter diameter, and eyed-ones taken from females, 94–97 mm long, run 2.4–2.7 mm and 1.7–1.9 mm in longer and shorter diameters respectively.

(19) The total number of external eggs differs in accordance with body-size of mother prawns, and the regression between total number of the eggs produced and body-length is positively nearly linear in trend. The total number of the eggs vary 170–350, 200–400, 250–500, and 350–550 in females measuring aproximately 90 mm, 100 mm, 110 mm, and 120 mm in body-length respectively.

(20) The stomach is without cardiac, pterocardiac, urocardiac, zygocardiac, and prepyloric ossicles, but a basal plate on the floor of the cardiac chamber and a pair of pyloric plates in the pyloric chamber only present.

(21) The main diet of this prawn consists of annelids and small-sized crustaceans, namely shrimps, amphipods, and schizopods.

(22) The prawn in question lives without any selection chiefly on small animals occuring on its natural environment.

(23) The main diet of those months from July to September consists of mysis (probably *Stilomysis camtschaticus* MARUKAWA), *Pandalopsis mitsukurii* RATHBAN, and amphipods.

(24) The feeding activity seems to decrease in the winter season inasmuch as the frequency percentages of the prawns having empty stomach are 66.66–87.50 in the winter season, and 18.96–38.33 in the other seasons.

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SUR LA NOUVELLE RAIE TORPILLE, *Crassinarke Dormitor*, GEN. ET SP. NOV., APPARTENANT A LA SOUS-FAMILLLE NARKINÉE

Kazunori TAKAGI

Les raies torpilles relatives aux Narkinés qui se trouvent au Japon étaient de deux espèces : *Narke japonica* TEMMINCK et SCHLEGEL et *N. dipterygia* (SCHNEIDER). Mais la torpille que l'auteur se propose de décrire dans ce mémoire paraît représenter un genre et une espèce nouveaux. La description ci-dessous se base sur un spécimen qui a été attrapé par le vaisseau-école de l'Université Nationale des Produits Maritimes de Tokio 《Shunkotsu-maru》 au mois de septembre 1950 au large de la côte d'est du cap d'Ashizuri, Kôchi Préf. (lat. 133° 07.2'E, long. 32° 43.2'N), à environ 80 toises de profondeur. Il s'est d'ailleurs reporté moindre spécimen de la Mer de la Chine orientale, qui lui a été offert par M. M. KATAYAMA. Pour le mesurage des parties du corps du poisson, l'auteur en est redevable à M. FOWLER (1941)[5], à moins qu'il en soit spécifié autrement.

L'auteur adresse l'expression de sa sincère reconnaissance à M. le professeur, Dr. I. KUBO de l'Université qui l'a dirigé cordialement durant cette étude. Il exprime aussi sa vive gratitude à M. le docteur K. MATSUBARA et à M. T. ABE qui l'ont aidé à se référer à des bibliographies, ainsi qu'à M. le docteur T. KAMOHARA qui lui a donné de précieux conseils. Il est aussi grandement obligé à M. le capitaine Y. SASAKI et à ses équipages, aussi bien qu'à M. M. KATAYAMA, quant aux spécmens en question.

Genus **Crassinarke** nov.

Les caractères du genre *Crassinarke* peuvent s'énoncer comme il suit :

Disque presque circulaire, épais et fort ; arrondi ou émoussé sur toute la marge, mais avec des plissures plutôt dégénérées près de la surface dorsale de la moitié arrière. Yeux petits, à peu près creux, mais encore pigmentés. Spiracules un peu plus grandes que les yeux, justement derrière les orbites ; leur marge est égale et ne fait pas de relief. Les valves frontonasales confluent l'une et l'autre vers une languette quadrangulaire, le libre bord de laquelle ne peut toucher qu'à la lèvre antérieure. Bouche petite, protractrice, environnée des lèvres charnues. Mâchoires pourvues de petites dents triangulaires pointues en arrière, et avec une base rhomboidale. Fentes

branchiales étroites. Queue plutôt mince, jamais comprimée verticalement comme chez *Narke*, avec de légers replis latéraux en pedoncule caudal (Fig. 1, H). Une dorsale. Caudale aussi nette que celle du genre *Bengalichthys*, presque faible, et arrondie postérieurement. Ventrales charnues, commençant justement sous l'extrémité des pectorales; l'angle frontal prolongé fait un lobe antérieur, et la marge latérale est concave (Fig. 1, A et B). Peau douce, dure et sans défense.

La sous-famille Narkinée se composait des trois genres: *Narke*, *Bengalichthys* et *Typhlonarke*. Tous les poissons japonais qui ont été rapportés à ce groupe étaient compris dans le genre *Narke*, comme il a été dit plus haut. Le genre décrit nouvellement ici se rapporte étroitement au *Bengalichthys* plutôt qu'au *Narke*, mais il se distingue bien des seconds, comme on le voit dans le Tableau 1.

Tableau 1. Caractéristiques essentielles suffisant pour distinguer le genre nouveau des autres, *Bengalichthys* et *Narke*. Citations d'après les auteurs entre parenthèses.

Caractère	*Crassinarke*	*Bengalichthys*	*Narke*
Disque	presque circulaire; arrondi sur toute la marge	the length about the same as the maximum transverse diameter (ANNANDALE); fleshy (PRASHAD)	subcircular (FOWLER); mince à l'exception de sa marge antérieure
Yeux	plutôt creux, mais peut-être fonctionnels, et encore pigmentés	degenerated to minute structures sunk in pits, and probably functionless (PRASHAD); colourless (ANNANDALE)	protruding (FOWLER); naturellement fonctionnels
Spiracules	sans relief sur leur marge	without raised edges (PRASHAD)	with raised edges (FOWLER)
Languette frontonasale	petite, recouvrant seulement la lèvre antérieure	small, extending up to the mouth but not covering it (PRASHAD)	large, covering mouth (FOWLER)
Queue	presque grêle, jamais déprimée comme celle des *Narke*, avec des replis latéraux légers	long, without any fold on lateral sides (PRASHAD)	short, with fold each side (FOWLER)
Ventrales	commençant justement sous l'extrémité du disque	not enclosed by the disc as in *Narke* (PRASHAD)	inserted below pectorals (FOWLER)
Peau	épaisse et dure	thick fleshy (PRASHAD)	soft (FOWLER)

Soit dit en passant, la sous-famille la plus voisine a été établie par FOWLER (1934)[4], qui regarde le *Bengalichthys* des trois genres comme identique au *Narke*, ainsi que ce fait GARMAN (1913)[6]. Selon PRASHAD (1921)[13] il semble

que c'est une méprise de leur part.

Génotype : *Crassinarke dormitor* gen. et sp. nov.

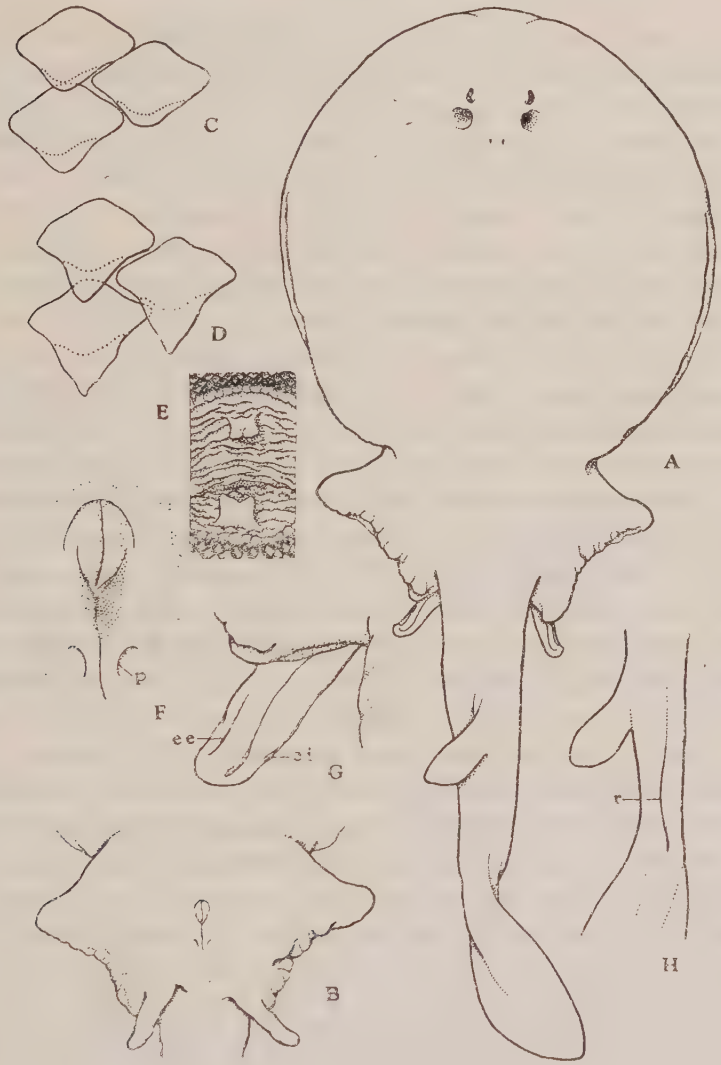

Fig. 1. *Crassinarke dormitor* gen et sp. nov. Type.— A, face dorsale, 1/2×.— B, face ventrale en partie des ventrales, 1/2×.— C, D, des dents sur la mandibule au rang extérieur (C), et au rang intérieur (D), 15×.— E, les appendices dans la cavité de la bouche, sur le palais et en bas, 1 3/4×.— F, ouverture anale ; p, pore abdominal, 1 3/4×.— G, organe copulateur gauche ; ee, entaille de l'extérieur ; ei, celle de l'intérieur, 1 3/4 ×.— H, face latérale en pedoncule caudal ; r, repli latéral, 1/2×.

Crassinarke dormitor gen. et sp. nov.

《Nemuri-shibiréei,》 nouveau nom japonais

Corps aplati, mais plus épais que celui du *Narke*; la tête et la partie antérieure du corps avec les pectorales, constituent un disque aussi large que long, antérieurement le bord en est arrondi et uni, en arrière sa marge est un peu rétrécie et crénelée; la distance du bout du museau au milieu de l'anus est plus longue que la queue sans caudale qui a deux fois la longueur du museau. Queue presque menue et cylindrique. Museau court, mais plus long que l'espace interorbital, contenu 2 1/4 fois dans la tête. Yeux petits, 11 1/4 dans la tête, 4 dans l'espace interorbital. Spiracules circulaires, tout près des yeux par derrière, un peu plus grandes que ceux-ci; leur marge est sans relief sur leur marge. Events presque grands, proche de la bouche; languette frontonasale assez grosse, mais petite, recouvrant seulement la lèvre antérieure; espace interonasal aussi large que la bouche, 9 1/4 dans la largeur du disque, 3 4/5 dans la tête. Bouche étroite, protractrice, entourée de plissures charnues; sur le milieu du palais est un petit appendice bilobé au bout, et en bas celui qui est le plus grand est entaillé sur toute la marge distale (Fig. 1, E). Dents menues, basses, plus ou moins pointues en arrière; elles sont plus aiguës au rang intérieur qu'au dehors (Fig. 1, C et D). Ouverture anale formant une paire de petits corps dans sa moitié antérieure: chacun d'eux est partiellement indépendant du corps en arrière (Fig. 1, F). Pores abdominaux croissants, près de chaque côté de l'extremité de l'anus. Organes copulateurs du mâle obtus et courts, aussi longs que le museau, confluant avec les ventrales par l'extérieur de la moitié antérieure; entailles de l'extérieur et de l'intérieur s'ouvrant près de l'autre côté des organes; l'une dans un sillon peu profond, plus longue que l'autre qui est directement sur la surface externe des organes (Fig. 1, G). Peau parfaitement douce, sans épine.

Dorsale petite, plus haute que la longueur, 1 4/5 dans la tête, justement sur le milieu des ventrales et de la caudale; son extrémité n'arrive pas à l'origine de la supracaudale et elle en est bien loin. Caudale 3 3/5 dans le reste du corps. Ventrales épaisses, plus ou moins concaves sur le côté extérieur; le bord dorsolateral de leur lobe postérieur forme une plissure distincte.

Brun au-dessus, légèrement foncé à quelques parts, spécialement au bord du disque et sur la partie médiane du corps, pas de tache spéciale. Dorsale et caudale brun-foncé toutes les deux, aussi bien que la marge des ventrales. Face ventrale blanc-grisâtre généralement, mais un peu brun-rougeâtre sur la part marginale du corps et des ventrales, et sur les entours des lèvres. Le

contour du disque, la marge antérieure des ventrales et la ligne de faîte des plissures blanchissent tous (Pl I, A et B.)

Ils sont décrits et figurés d'après un spécimen mâle de 283 mm de long au total, conservé dans l'eau formaline, au Laboratoire de Zoologie de l'Université, de la ville de Yokosuka, Kanagawa Préf.

L'espèce donnée ci-dessus se rapporte bien à *B. impennis* ANNANDALE, d'après lequel le genre *Bengalichthys* fut créé, qui le seul comprend. Mais elle en différe distinctement par la configuration des petits appendices dans la cavité de la bouche, par celle des dents dévelopées sur les mâchoires, et par la coloration du dos du poisson, aussi bien que par les traits énumérés dans le tableau précépent.

Quant au spécimen paratypique de la Mer de la Chine orientale (Pl. I, C et D), qui est une femelle et qui a 214 mm de long au total, il ressemble beaucoup à l'autre par plusieurs caractères importants. Mais on peut trouver entre les deux des différences très nettes:

Le disque du spécimen en question est un peu moins large que long, et la proportion de la largeur par la longueur est de 0.81; le disque du mâle est plutôt circulaire (il est peut-être mûr) et sa proportion est de 0. 95. D'un côté, chez *B. impennis*, cette proportion est, par exemple, de 0. 97 (♂, 175 mm de long au total) et de 0. 88 (♀, 125 mm de long au total), tous les deux d'après ANNANDALE, (1909)[1] et de 0. 77 (♀) chez un individu presque jeune de PRASHAD. De plus la queue du premier est un peu plus comprimée verticalement que celle du second, qui est presque cylindrique. Le problème à étudier maintenant est de savoir si la variation ci-dessus provient du sexe, ou de l'âge.

KAMOHARA (1943)[9] rapporte un seul spécimen mâle de 270 mm de long au total, de *Narcine dipterygia*, de Mimasé, Kôchi Préf., Japon. C'est lui qui fut autrefois décrit par le même auteur (1935)[8] comme une malformation de *Narke japonica*. Et à voir ses traits, entièrement décrits ci-dessous[a], et sa photographie, cette torpille paraît se rapporter à cette nouvelle espèce et non

a. 《La couleur du dos est brune et noirâtre en général, mais blanchie sur quelques points. Dorsale et caudale tout à fait blanches, mince, avec l'aspect d'une brosse au bout. Le dessous du corps blanc, avec des parties brunâtres en arrière. Corps plus grêle que celui des individus typiques [de *N. japonica*.] Les pectorales et les ventrales épaisses toutes les deux sur leur marge de derrière, dont la plissure est légèrement crènelée. Peau dure irrégulièrement, et corps robuste même dans l'eau formaline.》 (1935, p. 680; en japonais; le texte entre crochets est ajouté par nous.) Et 《vent nearer to anterior end of head than to posterior extremity of caudal; keel closely lateral edge of tail low. Teeth pointed, with tetragonal bases. Ventral with outer angle, the edge concave. Color blackish brown above, with white spots and edges, whitish below; dorsal and caudal white.》 (1943, p. 127.)

à *N. dipterygia*. L'auteur regrette de ne pas pouvoir s'assurer de sa supposition, parce qu'il se trouve que ce spécimen a été perdu pendant la dernière guerre.

Avant de finir, on peut mentionner les faits suivants comme renseignement:

(1) La description, avec une figure, de *B. impennis* par ANNANDALE[1] est trop courte ou trop simple pour être digne de confiance, come PRASHAD[13] l'a indiqué déjà. La nageoire caudale, par exemple, ANNANDALE la figure bilobée, quoiqu'il écrie dans son texte, qu'elle est ronde postérieurement. Sous ce rapport, par ses photographies du spécimen bien conservé, PRASHAD nous montre clairement qu'il faut suivre la description, non la figure. (2) *Astrape dipterygia* de DAY (1878–88)[2], indiquée par PRASHAD[13], est une espèce bien douteuse, qui ne peut pas servir de référence à *N. dipterygia* (SCHNEIDER), mais peut-être à *B. impennis* sur la plupart des particularités. (3) Suivant FOWLER[5], *N. dipterygia* a été révélé par MARTENS (1876)[11] de Yokohama, Japon. C'est l'unique document sur ce poisson au Japon.

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EXPLICATION DE LA PLANCHE I.

Crassinarke dormitor gen. et sp. nov.

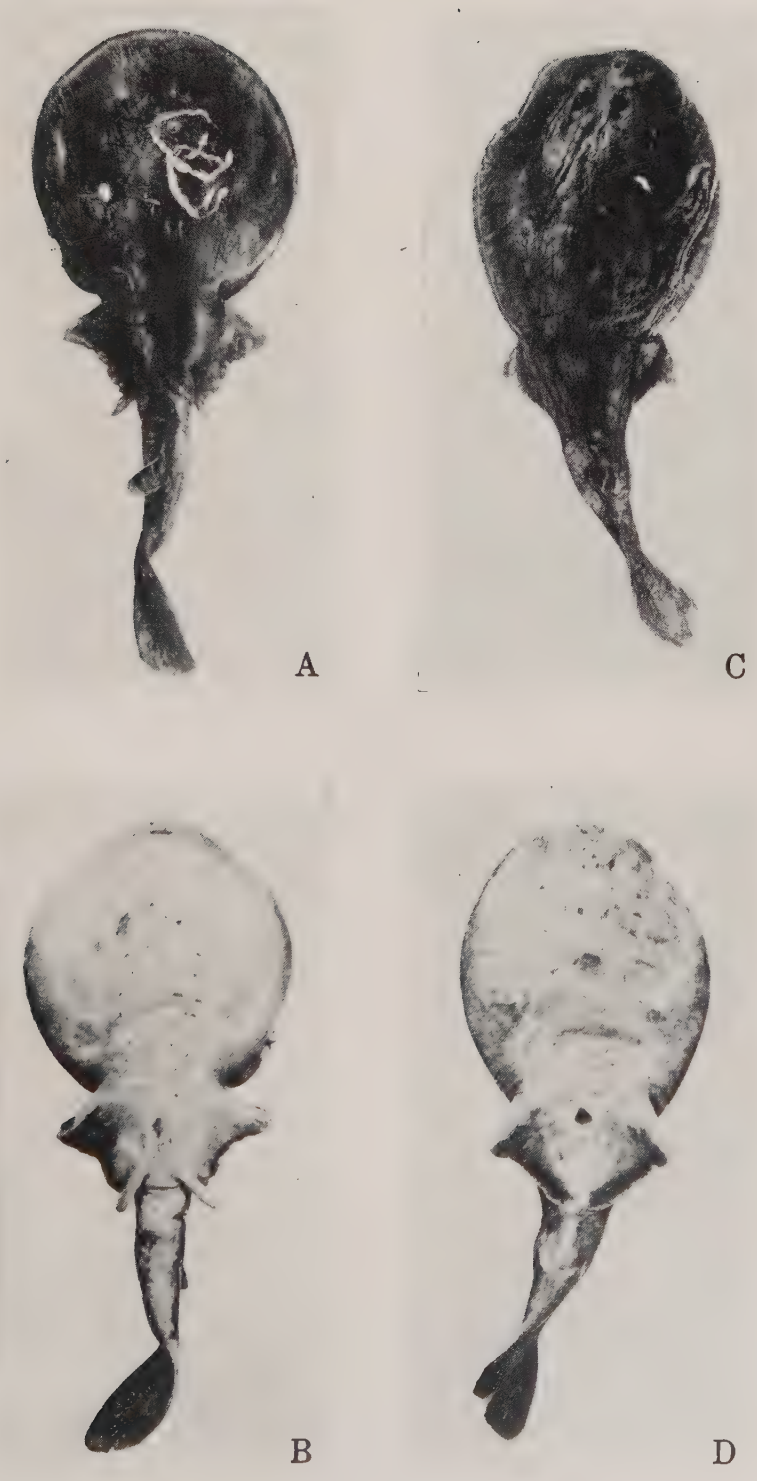
A.—Vue dorsale du spécimen typique de 283 mm de long au total, du large de la côte d'est du cap d'Ashizuri, Kôchi Préf.

B.—Vue ventrale du même.

C.—Vue dorsale du spécimen paratypique, qui a 214 mm de long au total, de la Mer de la Chine orientale.

D.—Vue ventrale du même.

PL. I.



ON A NEW MICROSPORIDIAN, *Plistophora anguillarum* n.sp., FROM THE MUSCLE OF THE EEL, *Anguilla japonica*

Toshikazu Hoshina

In Japan, only one instance of microsporidian infection of fishes *Plistophora* sp. parasitic to the epicardium of rainbow-trouts, was recorded by Dr. S. Takeda.

When the present writer was pursuing the study of the bacterial disease of eels at the Imperial Fisheries Institute in August, 1934, among the materials obtained from the Fish Cultural Laboratory at Yoshida, Shizuoka Pref., attached to the Institute, he found the diseased eels of the abnormal appearance, having swellings in places upon their body surface. Under the microscope in the muscle of the diseased eels, a microsporidian infection was proved. When in May, 1936, the parasitological investigations into the seriously illgrown eels among the one year cultured grass-eels at the Yoshida Fish Cultural Laboratory, was carried out by him, a considerable number of the diseased eels were found parasitized by the same parasite. Therefore, the writer examined, June to August of the same year, the ponds fishes of the Laboratory and of the neighbouring fish culture farm, and a large number of diseased eels caused by the parasites were obtained.

In Oct., 1936 the serious epidemic of the disease was found in an eel cultural pond near the City of Odawara, Kanagawa Pref.

The parasite attacks the trunk muscule of eels and when the infection is intensive, the muscular tissues may be entirely destroyed, so that the parasite is very injurious to the eel-culture.

The present species appears to be new to science and is described here under the name of *Plistophora anguillarum*.

Before taking up the subject, the writer wishes to express his gratitude to his respected teacher, the late Nobutaka Nakai under whose guidance the present work was carried out. Further he must express his hearty thanks to Dr. Makoto Koizumi, Professor of Keiô University for his kindness in reading the original manuscript. His thanks are also due to Dr. Yaichiro Okada, Professor of the Prefectural University of Mie, who kindly offered him facilities for the publication of this work, and to Mr. Kaku Ohshima, Chief of the First Research Section of Sericultural Expriments Station for his kindness in placing at his disposal the literatures necessary for the present study.

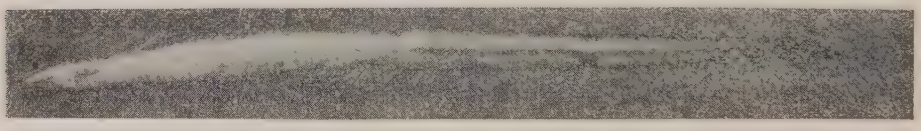
1. MATERIALS AND METHODS

The materials were collected in May and July to August, 1936 at the Yoshida Fish Cultural Laboratory, and in Oct. 1936 at the fish-cultural ponds near the City of Odawara.

The materials were fixed in 10% formalin, or *F. S. E. mixture solution or Bouin's solution for sectioning, and sectioned under paraffin method, and stained with Delafiel's haematoxyline-eosin, or Heidenhain's iron-haematoxyline, or safranin-haematoxyline, or others. The fresh smeared preparations were fixed in Schaudinn's solution with acetic acid or F. S. E. solution and stained with Giemsa or iron-haematoxyline.

2. MODE OF PARASITISM

The present species is a muscular parasite of eels, and in the muscle fibers numerous small white cysts are formed by the parasite. When the infection is heavy, the entire trunk muscle is so crowded with the cysts that the muscular tissues swell out, and as the disease advances, the muscular tissues disintegrate and the diseased fishes become to show the characteristic symptom, for instance, the body surface swells in places (Textfig. 1.)



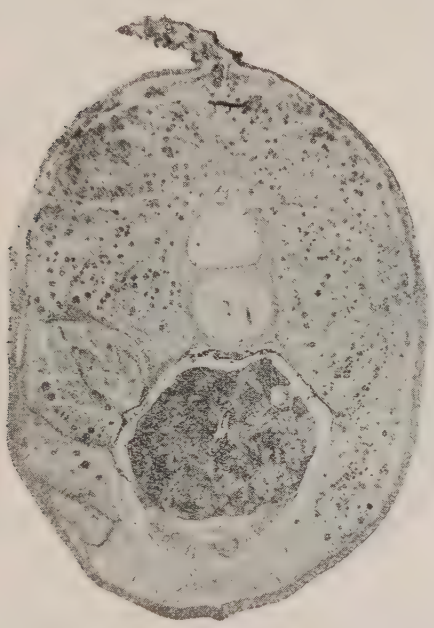
Textfig. 1. Showing the external appearance of the eel (*Anguilla japonica*) received the infection of the parasite (*P. anguillarum* sp. nov.). This speciemen did not so clearly mark the swelling. Photo. Asao, Kumada. ⊢————⊣ 5 cm

When man palpates such diseased eels, he feels stiff on the swelled parts and soft on the not swelled parts. When the diseased fishes are examined to cut open them along their vertebral columns, the muscular tissues assumed an opaque milky white color and pap-like nature, especially on the parts feeled soft by the palpation. In the pap-like substance an immense number of the microsporidian spores were contained. From the facts it is evident that the hard and swelled parts are in the state where a large number of the cysts have been formed in the tissues but they are not disintegrated, and the soft parts indicate the complete disintegration of the tissues.

In the section preparations of heavy infected parats numerous cysts scattered all over the muscular tissues were noticed (Textfig. 2).

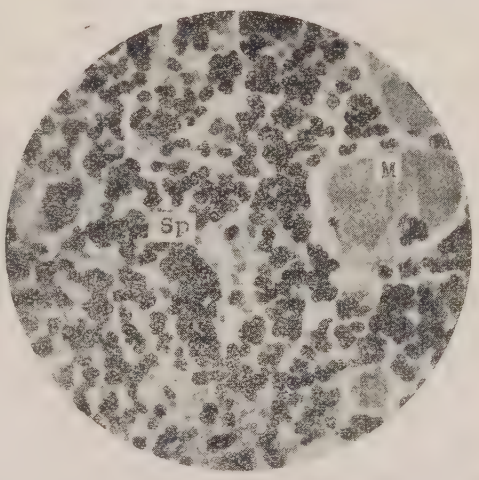
* 8% formalin 10 c.c.+sarturated aqueous solution of corrosive sublimate 10 c.c.+glacial acetic acid 0.2 c.c.

In the collapsed tissues, it was observed that they were filled with numerous spores (Textfig. 3).



1 mm

Textfig. 2. The cross section of the body of diseased eel, numerous black spots scattered over the muscular tissue are the cysts of the parasite. Stained with Safranin-haematoxyline.



30 μ

Textfig. 3. Showing the collapsed tissue in cross section. Stained with Safranin-haematoxyline. M. – – – Disintegrated muscular bandle. Sp. – – – Spores.

When the infection was intensive, the spores not only in the muscle fibers but also in the fascia and subcutaneous adipose tissues were seen. Further, a few infiltrated spores in the heart, spleen, kidney, lever and intestine were observed, but in these tissues as well as in the fascia and subcutaneous adipose tissues the cysts were not formed.

Among the above-mentioned organs, the kidney and instestine were frequently parasitized by the parasite, and the spores, at the kidney in the lymphoid tissues and at the intestine in the submucosa tissues were found. But any pathological changes were not seen in these organ tissues.

In the case of the larger diseased eels (body length 40 cm long or so), the color of the integument was normal, but in the case of the smaller eels, the heavy infected parts assumed somewhat milky white color.

3. CYST

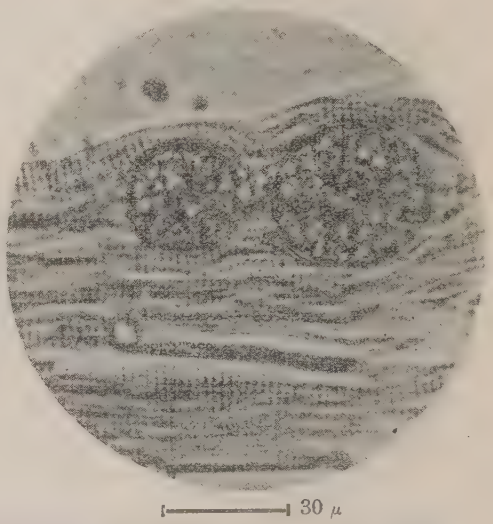
The cysts are whitish and spherical or ellipsoidal bodies with a thin

membrane (1.1~1.3μ thick). They present the appearance of a sporont, but in their bodies numerous sporonts filled with spores are contained. The cross sections of the cysts are circular. The dimensions of the cysts vary to a considerbly large extent, and are 28~195μ×26~117μ (Textfig. 4 and Pls. 2., fig. 57).

The membrane of the cysts is structureless and clearly stainable with ordinarly staining dyes, and may be a product of the parasite itself. Around the membrane, there is no other membraneous tissues originating from host's tissues.

The sporonts in the cysts are spherical or ellipsoidal in form measuring 13.4~18.0μ×10.2~17.0μ in their fresh state.

Each sporont ordinarily contains 4 or 8 spores, sometimes it was observed that one sporont contains 16 spores or more (Pls. 2. figs. 58–60). Further there were such cases where in one sporont 2, 3, 5, 6, 7, 9 spores are contained.



Textfig. 4. Showing the cysts in the muscle fibers. Unstained preparation.

The sporont that located in the various organ tissues ordinarily produced 1, or 2 or 3 spores.

In the case of microspore, one sporont generally produces 16 spores or more (Pls. 2., figs. 56).

4. SPORE

The spore is ovoid, and the one side somewhat concave and the cross section almost circular. In the fresh state, the anterior portion of the spore seems filled with protoplasm mass and vacuous in the greater portion of the posterior. In this portion 3 or 4 transverse lines can be seen, and this lines may be indicative of the both edges of the coilled polar filament (Pl. 2., fig. 46).

The polar capsule is not visible and the coils of polar filament are indistinct. However, when the stained preparations are examined, the polar filament which reaches from the anterior end to the posterior portion of the spore is seen. There-fore the filament seems coiled in the posterior vacuous portion (Pls. 2., fig. 45).

The sporoplasm is the like of an narrow girdle and locates at about the posterior end of the anterior third of spore.

The riped spore with one sporoplasm nucleus is spherical and compact and measures about 1.5μ in diameter.

In the fresh state, the macrospore measures 6.7~9.0μ long by 3.3~5.3μ broad and microspore 2.8~5.0μ long by 2.0~2.9μ broad. The details are compiled in the table 1.

Table 1. Measurements of spores.*

		Number of individual measured	Range	Mode	Mean	S. D.	C. V.
(1)	Length (μ)	100	6.65~9.04	7.80~8.00	7.858±0.047	±0.704±0.044	8.959±0.431
	Breadth (μ)	100	3.33~5.32	4.60~4.80	4.514±0.026	±0.390±0.019	8.639±0.413
	$\frac{\text{Length}}{\text{Breadth}}$	100	1.5~1.8	1.6~1.7	1.64±0.007	±0.101±0.005	6.71±0.32
(2)	Length (μ)	60	2.79~4.97	3.80~4.00	3.59±0.05	±0.54±0.03	15.11±0.95
	Breadth (μ)	60	2.00~2.93	2.40~2.60	2.46±0.02	±0.26±0.02	10.57±0.66
	$\frac{\text{Length}}{\text{Breadth}}$	60	1.3~1.8	1.5~1.6	1.46±0.01	±0.12±0.01	8.22±0.51

* Nemeczek's hanging drop preparations prepared from fresh materials and measured by Schraubenmikrometer. (1) --Macrospore. (2) --Microspore.

It was difficult to make the polar filament extrude. After various attempts were tried, the extrusion of the polar filament was often observed when allowing the fresh smeared preparations dry naturally.

The polar filament measures 400~440μ long (Pls. 2., fig. 62).

5. SCHIZOGONY

The schizonts are observed in the muscular tissues. In the section preparations they show spherical, pyriform or elongated form, and their demensions are 4.3~11.2μ×3.5~6.8μ.

The cytoplasm is structureless and provided with a spherical, and compact nucleus (Pls. 1. figs. 8-9). In the fresh state, they show a rounded from generally, and their movement could not observed (Pls. 1 fig. 7). The schizonts were rarely found in the epithelial cells of the host's instestine, and they are spherical and measure 2.66~3.72μ in diameter. Sometimes it was observed that the schizont multiplies by binary fission in that tissues and the divided schizont seems sometims to develop directly into a sporont (Pls. 1., figs. 1-6).

* Nemeczek, A. : Arch. Protist. kde. Bd. 54, S. 137-149, 1925.

The schizont which invaded the muscular tissues, multiplies by binary division and a large number of schizonts are formed. Thus, the produced schizont penetrates the musclefibers and develops into a cyst. The cyst may be formed in the following ways. (1). The schizont grows into a large trophozoite or plasmodium and in its body a large number of sporonts are formed and afterwards each of them produces spores and as the development advances the trophozoite transforms finally into a cyst (Pls. 1., figs. 16~19, Pls. 2., fig. 57).

When the muscular tissues of the diseased eels are examined on careful dissection, the young trophozoites may be detectable.

The general outline of the bodies is like a tadpole measuring 60~70μ×20~30μ. The cytoplasm of the bodies is divided by indistinct partitions and dotted with small nuclei. The fig. 19 in Pls. 1. shows the young trophozoite. The section preparations of the young trophozoite show various stages of its development. In the first place, mononucleated bodies are observable (Pls. 1., fig. 20). As they grow, the nuclear division takes place two times in succession and produces the stages with two and four nuclei. The four nuclei stage is followed by cytoplasmic division and four cells are produced and each of them may be the earliest stage of the sporont (Pls. 1., figs. 21~24).

The nucleus of the sporont divides and produces ordinarily four or eight sporoblast nuclei, and afterwards each of them produces a spore. Through these courses the young trophozoite transforms into a cyst which contains numerous spores. (2). The schizont produces a thin membrane around itself and undergoes successive binary division and numerous mononucleated bodies are produced in the envelope and each of them develops directly into a sporont and the schizont thus transforms into a cyst (Pls. 1., figs. 12~15). (3). The schizont grows without developing into a large trophozoite and the nuclear division takes place and numerous small nuclei are produced as a result, after-wards the cytoplasmic division occurs to surround each nucleus and numerous mononucleated bodies are formed, and each of them will transforms directly into a sporont. And a cyst is formed (Pls. 1., figs. 26~28).

6. SPOROGONY

As already stated, the sporont in the cyst produces ordinary 4 or 8 sporoblasts (Pls. 1. fig. 25). The earliest stage of the sporont is a mononucleated body as shown in Pls. 1., fig. 24. As it grows a membrane is produced by itself around it, then the nuclear division takes place successively two or three times and 4 or 8 nuclei are formed. Afterwards, each of the nuclei is beset with condensed protoplasm and mononucleated forms are produced (Pls.

1., figs. 29~32).

Thus produced mononucleated forms are the earliest stage of the sporoblast and afterwards each of them develops into a spore.

As above mentioned, the sporoblast is mononuclear at first, but during the development, the nuclear division takes place and various nuclear stages appear. In the smear preparations, the one, two, three, four and five nuclear stages were observed (Pls. 2., figs. 33~38).

The nuclear division and the sporulation may be as follows: By the first division the two nuclei are formed and the one forms the shell valve and the polar filament, and another remains for sporoplasm nucleus, however, this nucleus is followed by two times successive binary division and four nuclei are formed, further it may occurs during the sporulation disintegration of the two nuclei, and the remaining two are followed by autogamy and a synkaryon is formed, which remains as sporoplasm nucleus of the completed spore (Pls. 2., figs. 33~45).

Somewhat advanced sporoblast in sporulation presents an oval form and as the shell valve-formation advances it begins to form the polar filament and by that time the polar filament is completed as well as the shell valve.

The schizont which has penetrated into the inter muscular connective tissues, subcutaneous adipose tissues or various inner organ tissues, produces spores without forming a cyst. The sporonts which were observed in the inter muscular connective tissues, presented an irregular or elongated form and uninuclear or several nuclear. Their nuclei are comparatively volminous and each of them transforms into a aporoblast (Pls. 2., figs. 48a~48d).

Next, the microspore-formation seems due to the heteropolar division of the schizont. By the division the small schizonts are formed and they grow into a small trophozoite dotted with small nuclei, and from each of them a sporoblast may be formed and the sporoblast seems to transform into a microspore (Pls. 2., figs. 50~56).

In the sectione preparations, the small schizonts are pyriform measuring 3.0~4.0μ×2.0~3.5μ and provided with small nuclei (Pls. 2., fig. 49).

The content of the microspore in one sporont is variablle, and generally it counts 16 spores or more.

As above stated the microspore-formation is clearly distinguishable from the macrospore-formatiom, but in very rare cases, the microspores were found in the same cyst that contains macorspores, however in one spront the occurence of the both types of spores was never seen.

7. EFFECT OF THE PARASITE UPON THE HOST

The proper seat of infection of this parasite is the trunk muscle of

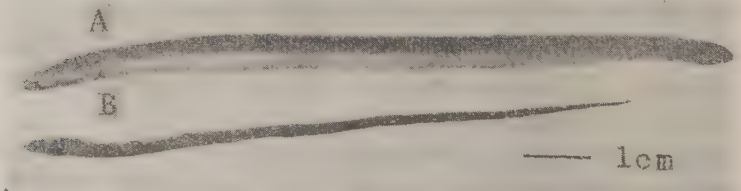
eels and when the infection is intensive the almost entire of the trunk muscle is invaded and the body is deformed by so numerous parasites. As the state advances the muscular tissues are entirely broken down, so the host exceedingly suffered and becomes weakened gradually and dies in a certain time. But, the course of the disease is not acute and the diseased fishes are alive for a considerable long time, even if they were infected intensively. However, during the course, the natural recovery may be hopless.

In the state where only the young trophozoites or the cysts have developed in the muscle fibers, the surrounding musle fibers showed no abnormal sign as in the cases of the host's tissues parasitized by *Plistophora typicalis* or *P. ehrenbaumi* (see textfig. 4).

In the ruptured tissues, the infiltrations of lymphocytes and the hemorrhage were sometimes observed, further phagocytosis by the monocytes was seen (Pls. 2., fig. 62). There were also no remarkable changes in the blood corpuscles. The numbers of red blood corpuscles of the diseased fish which were selected as the infection of same degree were within range of 2,068,000~3,216,000 and avareage 2,924,000 per cmm. (number of individual examined 66; Body weight 4.0~25.0 g.; on the 3 to 8 Oct; of 1936).

According to Dr. N. KAWAMOTO (1929)*, the number of red blood corpuscles of normal eels (*Anguilla japonica*) shows in the case of smaller ells (bydy weight 0.78~1.25 g.), medium (" 22.00~104 50 g.), and larger (" 99.00~152.00 g.) average 2,855,000, 2,572,000 and 2,546,000 per cmm. respectively. Compared the red blood cell count of diseased fishes with this value, the count of the diseased eels shows somewhat higher value. Probably this may be the apparent value of some period in the course of the disease.

At any rate, although the mortality of the diseased fish may be not



Textfig. 5. Showing the effect of the parasite upon the growth of the host. One year cultured grass-eels. A. - - - Normal eel, B. - - - Diseased eel.

* Kawamoto, N.: Science Reports of the Tôhoku Imperial University, Fourth Series, Biology, Vol. 4, 1929.

strikingly observed, the effect of the parasite upon the host is severe. In the case of smaller eels, it hinders extremely the growth of them as it attacks the trunk muscle and destroys the tissues (Textfig. 5).

For the same reason, in the case of larger eels, on account of the parasite, they may lose their values as foods. Moreover, as the parasite possesses a strong infectious power, it is a noticeable parasite to the fish-cultural industry.

8. COMPARISON AND DISCUSSION

The present microsporidian species inhabits in the trunk muscle of *Anguilla japonica* and gives rise to numerous white cysts assuming a spherical or ellipesoidal form and measuring $28\sim195\mu\times26\sim117\mu$ in the muscle fibers. The cysts are surrounded by a thin membrane and contain many sporonts, in each of which 4 or 8 spores generally contained, but sometimes it is observable that one sporont contains 16 spores or more. The spores are oval in form and measure $6.7\sim9.0\mu\times3.3\sim5.3\mu$ in the case of macrospore and $2.8\sim5.0\mu\times2.0\sim2.9\mu$ in the case of microspore (both in the fresh state).

According to KUDO's classification the present species may be placed in the genus Plistophora of the family Nosematidae, because the spore presents an oval form and the sporont produces more than 16 spores.

The present species closely resembles *P. longifilis* SCHURBERG 1910 in the shape of spore, but differs in the size of spore, in the vegetative form and in the seat of infection etc..

Further the present form resemles *P. typicalis* GURLEY, 1893, *P. macrospora* CÉPEDÉ, 1906, *P. Blochmanni* ZWÖLFER, 1925 and *P. ehrenbumi* REICHENOW 1929 in the form of spore, in the seat of infection or in the mode of infection etc., but the present species is distinguished from all these members by the size of spore, the structure of spore or the vegetative form.

The microsporidian parasites to Japanese fishes, only one species, *Plistophora* sp. that is parasitc to the epicardium of Salmo irideus in the River Chitose in Hokkaido is recorded By Dr. TAKEDA (1933). This species is entirely different from the present form in the size of spore or in the vegetative form. For that reason, it seems to the writer that the present species is a hitherto unrecorded species, hence he provisionally refered it to a new species, *P. anguillarum* n. sp.

The investigations in regard to the life cycle of Microsporidia were carried out by many researchers. The results of those investigations are variable, but they may be briefly summarized in the following two different conclusions. One of the conclusions is as follows: When the schizogonic phase

changes to sporogonic phase, two nuclei are fused by isogametes, anisogametes* or autogamy of two nucleated body and form the sporont.

Another conculsion shows, that the sporont arises without the nuclear fusion in any form.

Both conclusions are supported by many instances. In the present species the writer could not find any nuclear fusion when it changes from the schizogonic phase to sporogonic phase.

Several authors noted the occurence of five nuclei or six nuclei in the sporoblast during the sporulation and that the spore is formed by this five nuclei differentiating two for spore membrane, one for polar capsule and the filament and the remaining two for sporoplasm. On the other hand, other several authors stated, that the sporoblast transforms into a spore in the state of one or two nuclear during the sporulation.

The sporoblast of the present species gives rise to five nuclei as the former stated. However, the writer thinks that the sporoblast of the present species may transform into a spore in the following way: the one nucleus forms the shell valve and the polar filament and remainings becomes for sporoplasm nuclei, but two of them disintegrate later (perhaps reduction phenomena) and the remaining two form a synkaryon by autgamy after the sporulation. Therefore, in the sporoplasm of matured spore one nucleus is seen, and the sexual phenomena may occur thus in the sporoplasm of completed spores.

The interpretation somewhat related to those of Stempel (1909) and Georgéwitch (1927, 1929).

It is the well known fact, that Microsporidia, although in the case of one and the same species occuring in a single host, produces spores which vary in size to a considerable large extent. Regarding the cause of this phenomenon some interpretations are given by several authors. Naville (1931) pointed out that the phenomenon is based on two causes and he said "Le dimorphisme ou le polymorphisme sporale auraient, suivant les cas, deux causes destinctes: la différenciation plus ou moins hôtive des sporoblastes dans le sporonte (dimorphisme sporal de Reichenow) d'une part, et d'autre part, la parthénogénèse (dimorphisme entre sporontes macronucléés et micronucléés de Guyénot et Naville et Guyénot et Ponse)."

In the present species, the two types of spore-formation—the macro and microspore-formation are also observable. But the cause of the microspore-formation does not agree with the theory of Naville. Probably it may be referable to the heteropolar division of the schizont, and it may be conjectured

* The occurence of anisogametes was reported by Guyénot et Naville (1922) for *P.* (*Glugea*) *danilewskyi*, but the copulation was not observed.

that the cause of the hetropolar division is based on the condition of nutrition of the schizont or the partial resistance of the host's tissues.

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20. ———: *Plistophora Blochmanni* II (Bemerkungen zu einer Microsporidienarbeit von P. Debasieux). Ibd. Bd. 54, S. 341–354, 1925.

EXPLANATION OF FIGURES.

Plate 1.

All Drawings except Figs. 7 and 19 were made from the section preparations stained with Delafield's haematoxyline-eosin or Heidenhain's iron haematoxyline; the materials were fixed in F. S. E.; and all Figures except Figs. 7 and 19 are same magnification.

Figs. 1. to 6. Showing the schizonts and the young sporonts, parasitic to the epithelial cells of the host's intestine; 1. ---schizont, 2. ---earlier stage in division, 3 and 4 --- state in division. 5 and 6---sporont or young sporoblast.

Figs. 7. Schizonts parasitic to the muscular tissue, in the fresh state.

Figs. 8. to 10. Showing the schizonts to the muscle fibers; 8. ---schizont, 9. ---state in division, 10. ---showing two schizonts which are in a state of heteropolar division.

Figs. 11 to 15. Showing formation of cyst by binary division of schizont; 11. --- schizont or sporont surrounded with a thin membrane. 12. ---stage in division, 13. ---four cellular stage, 14. ---twelve cellular stage, 15. ---stage of many sporonts formed in one envelope.

Figs. 16 to 18. Schizonts or young trophozoites, perhaps developing into plasmodium; 16. ---nuclear division, 17. ---two nuclear stage, 18. ---two nuclei are in the division and two are resting.

Fig. 19. Young trophozoite or cyst from musculer tissues of materiels preserved in formaline.

Figs. 20 to 25. Showing sporont-formation in young trophozoite or cyst; 20. --- mononucleated body in the young cyst, 21. ---stage in nuclear division 23. ---four nuclear stage, 24. ---showing the interior of a young trophozoite or cyst, the four grouped cells may be the earliest stage of sporont. 25. ---sporont in cyst

Figs. 26 to 28. Showing the cyst-formation from the plasmodium; 26. ---plasmodium with numerous small nuclei, 27 and 28 ---from the nuclei many mononucleated bodies were formed, each of them may be sporont.

Figs. 29 to 32. Showing the development of sporont in cyst; 29 and 30 ---young sporont in nuclear division, 31 ---young sporont with four nuclei, 32 ---stage in sporoblast-formation, the protoplasma condensed around the nuclei.

PL. I.

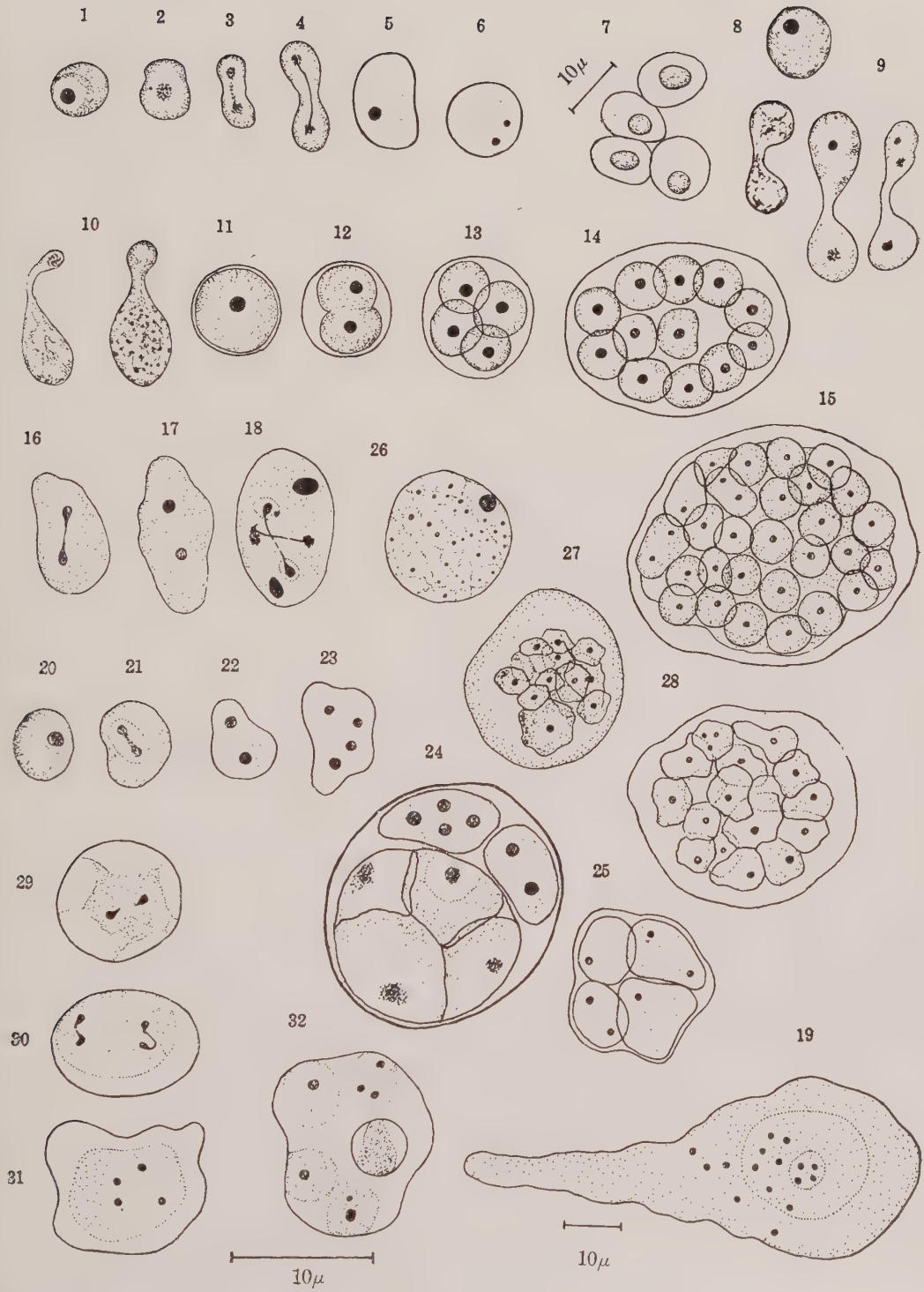
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Plate 2.

Figs. 33 to 39 and 47 from smear preparations, stained with Giemsa fixed in Schaudinn; Figs. 40 to 45 from section preparations stained with Heidenhain's iron haematoxyline, fixed in F. S. E.; Figs. 48a to 48d from section preparations, stained with Delafield's haematoxyline-eosin, fixed in formalin; Fig. 49 and 55 to 57 from section preparations stained with Heidenhain's iron haematoxyline, fixed in F. S. E.; Figs 50 to 54 and 61 from smear preparations, stained with Giemsa, fixed in Schaudinn; Figs. 33 to 47, 49 to 56 and 61 under magnification of ca. 2400 : 1: Figs 48a to 48d and 58 to 60 under magnification of 1200 : 1.

Figs. 33 to 42. Showing the transformation of sporoblast into spore; 33 – – – stage in mononuclear, 34 – – – two nuclear state, 35 – – – stage producing three nuclear, 36 – – – stage of three nuclear, 37 – – – four nuclear state, 38 – – – five nuclear state, 39 – – – two nuclei in disintegration, 40 – – – state in polar filament-formation, sporoplasm of three nuclear, 41 – – – somewhat advanced stage than fig. 40, 42 – – – young spore, sporoplasm in two nuclear.

Figs. 43 to 44. Showing the autogamy of two nuclei of sporoplasm.

Figs. 45 and 47. Completed spores.

Fig. 46. Spore in fresh state.

Figs. 48a to 48d. Showing the sporont parasitc to the inter muscular connective tissues.

Figs. 49 to 55. Showing the trophozoite or sporont which produces microspore; 49 – – – small schizont, 50 – – – state of three nuclear, 51 – – – state of six nuclear, 52 – – – sporont with one microspore and three sporoblast nuclei, 5 3 – – – sporont with five microspores and three sporoblast nuclei, 54 – – – sporont with one microspore and twenty seven sporoblast nuclei, 55 – – – sporont with fourteen young sporoblasts, in this case, all the sporoblasts are in same degree in development.

Fig. 56. Sporont with sixteen completed microspores.

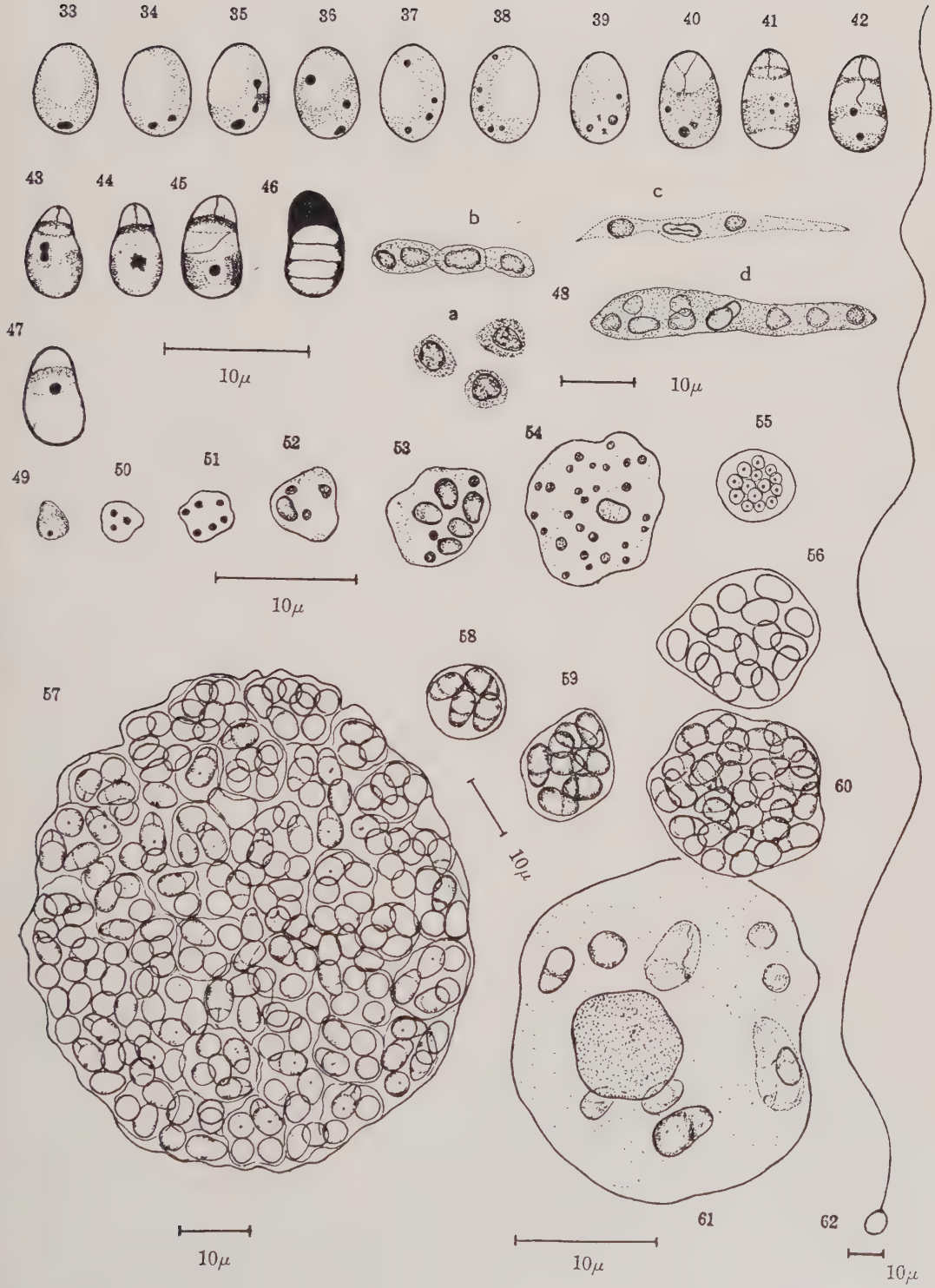
Fig. 57. Cross section of cyst.

Figs. 58 to 60. Showing the sporont from cyst with macrospores, unstained preparations.

Fig. 61. Phagocytosis.

Fig. 62. Fresh spore with extruded polar filament, semi diagramatic.

PL. II.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DESCRIPTION OF SOME FOSSIL FISHES AND PRAWNS FROM JAPAN

Hiroshi Niino

(With 7 Plates, 2 Text figures)

I. INTRODUCTION

The fossil fishes and prawns in this paper were collected from two localities, Gunma Prefecture in Kwanto district and Tottori Prefecture in Sanin district.

The specimens have been preserved in the collection of the Imperial Fisheries Institute (Tokyo University of Fisheries, renamed), but now, some of the specimens are not to be found in the collection, for they were damaged by war after their specific determination were finished. In this paper tht writer described four species of fossil fishes and one speciés of prawn, but the specimens at hand are the remnants of the collection ruined by war.

		Number of specimen at the time of determination	After war
	Stichaeus	2	None
	Protopsetta	1	None
Fish	*Sebastodes*	3	1
	Scomber	6	6
	Iquius	3	1
Prawn	*Pandalus*	2	1

Figure. 1. A diagramatic map showing the locality of fossil fishes and prawns.

II. THE FOSSIL FISHES AND PRAWNS FROM GUNMA PREFECTURE

The fossils were found in the Tertiary deposit along the river cliff at Orita, about 4 km. south of Sawatari hot spring, Sawada-Mura, Azuma-Gun, Gunma Prefecture. (Fig. 1.)

This fossil locality was reported by Mr. Honda[1] of the Scientific Museum at Ueno, Tokyo, but no detailed study on fishes was made. The writer visited Sawada-Mura and found a new fossil bed on the leaches about 300 m. under the fossil bed reported by Mr. Honda. (Fig. 2.)

(1) K. Honda: On the fossil from Sawada-Mura, Azuma-Gun, Kozuke. Natural Science and Museum. No. 13, 1931. Published from Tokyo Scientific Museum, Ueno, Tokyo.

Fig. 2. A photograph of upper fossil bed at Orita, Sawada-Mura, Azuma-Gun, Gunma Prefecture. ×—Fossil bed.

1. Stratigraphic note

The Tertiary formation of this district is essentially made up of the alternation of various kinds of tuffs which are either sandy or shaley and occasionaly agglomeratic. The strike of the strata as a whole running N.45°E. and dipping 15°S.

The fossils in the Tertiary Formation are plants remains, marine molluscs, Prawns and fishes. The visible strata containing fossil fishes are two. The upper horizon consists of the alternation of thin laminated tuffaceous shales in which there is a layer about 30 cm. in thickness which containing numerous large fossil fishes. This fossil bed is covered with the scoriaceous brecciated tuff which contains molluscan fossil (*Thyasira bisecta* CONRAD, *Lucina* sp.).

The lower fossil bed consists of the alternation of thick tuffs and tuffaceous shales followed by agglomerate. The fossil fish and prawn were found in the concretion from the tuffaceous shale in this bed. Though the number of fossil fish is large, but that of species rather small.

The species so far determined are as follows:

Molluscs	*Thyasira bisecta* CONRAD	Rare
	Lucina sp.	Rare
Prawns	*Pandalus oritaensis* sp. nov.	Common
	Leander sp.	Rare
Fishes	*Scomber nomurai* sp. nov.	Abundant

Protopsetta kubotai sp. nov.·····Rare
Sebastodes kanezawai sp. nov.·····Common
Stichaeus matsubarai sp. nov.·····Rare

Though the fossils belong to new species, except mollusca, each of them resembles the species which are distributed in the cold water, i.e. the northern sea around Japan or the deep sea below 200 m. in depth at the central Japan.

It is a noticeable fact that the plant remains associated with fossil fauna, but they may not always indicate the shallowance of the fossilized condition or be in shore, for the writer has experienced the land plants have been dredged from a depth below 200 m.

The preservation of fossil is very good; in some specimens, and such soft parts as gills or rays are well preserved.

Judged from the following focts: 1) fossils are very well preserved and it show that the fishes had not been decomposed before fossilized. 2) Occurrence of the fossils are restricted within a narrow layer. 3) The matrix are made of various kinds of tuffs. 4) The fossil bed is followed by a agglomerate or scoreaceaous tuff layer; it seems that the fossil fishes and prawns were exterminated by volcanism and suddenly embeded in the stratum.

The writer wishes here to express his sincere thanks to Dr. K. MATSUBARA and Dr. I. KUBO for their kind guidance in the determination of fossils, and also to Dr. OKADA for his kind guidance in photography.

2. Description of species.

Pisces.
Series Teleostei.
Order Percomorphi.
Family *Scombridae*.
Genus *Scomber* (Artedi) LINNAEUS. 1817.

Scomber nomurai, new species.
(Pl. I, 1-2; Pl. II, 1-2; Pl. III, 1-2.)

These fossil fishes were found in the upper fossil bed only. The preservation is very good. Opercles, scales, vertebrae and fin are determinable, but finlets can be observed on some confined specimens only and such feeble finlets are invisible on the most specimens; because the caudal region of these fishes were covered with scales. The separation of a perfect specimen from the fossil bed is very difficult, for the fossil fishes are crowded in a thin layer and each individual lie one upon another. There is another distress in the determination of fossils; for it seems to the writer that this fossil school are essentially made of *Scomber*, but among them some *Decapterus* of the same size are mixed.

The following description is based on the specimens on hand which are comparatively well preserved.

Diagnosis: — Body fusiform, rather elongated, tapiring into a slender caudal pedancle which bear a long and deeply forked caudal fin.

The depth of body about 5.3 in length. Head large and pointed about 3.4 in length of body, eye 5.1 in length of head, snout 2.8. The upper surface of head naked but the operculum scalely. The cleft of mouth large, premaxillary protoractite, maxillary attaining under the central part of orbit.

Teeth on upper and lower jow fine and conical. Operculum large and wide, subopercle and interopercle very narrow, preopercle large and triangular with a distinct radial strips for backward.

Two dorsal fins; the first dorsal with 11 spines, the second dorsal 1 spine and 13 rayes followed by five finlets. The second dorsal is shorter than the first and the interspace between them are far wider than the base of the first dorsal as wide as 0.6 in length of head. The second dorsal fin rises comparatively backward, 1.7 in length of body. Anal 1 spine and 11 rays, proceeded by 1 isolated spine and followed by five finlets. The anal fin rise the prosterior one-third of the body. Pectral thoracic rather small.

Measurement on five specimens of Scomber nomurai sp. nov.

Items	Reg. No. 111	Reg. No. 113	Reg. No. 115	Reg. No. 116 (Lower)	Reg. No. 116 (Upper)
Total length	36.5cm.	—	40.9cm.	—	—
Body length	34.2	—	37.8	26.5cm.	24.0cm.
Depth of body	4.8	5.5cm.	7.2	—	4.5
Length of head	10.7	9.0	11.2	—	—
Deph of head	—	—	5.6	—	—
Length of eye	1.6	1.6	2.2	—	—
Length of snout	3.6	3.0	4.0	—	—
Length of maxillary	—	—	4.4	—	—
Length of caudal pedancle	1.7	—	2.3	2.0	—
Depth of caudal pedancle	—	—	2.0	1.4	1.4
Length of caudal fin	—	—	3.1	3.8	3.2
Wideth of caudal fin	—	—	7.1	6.9	6.3
Length between anterior part of anal and caudal fin	—	—	11.4	—	11.3
Length between snout and anal fin	—	—	26.8	—	—
Length between posterior part of 2nd dorsal fin and caudal fin	11.6	—	—	11.6	11.8
Length of ventral fin	—	2.5	3.3	—	—
Length of pectral fin	—	—	2.7	—	—

Vertebrae 31(15+16); rather strong, longer than wideth, with two longitudinal keels on the surface.

Scale cycloid, very large near the pectral fin, but the others small.

Remark:—The general appearance of this fish closely resembles *Scamber japonics* HUTTOUYN[2] or *Scomber colias* GMELIN[3] and also their internal skeleton, but this fossil fish scale coveres trank; such large scaled species, have never known in this genera.

Locality:—Upper fossil bed, Orita, Sawada-Mura, Azuma-Gun, Gunma Prefecture. Reg. No. 111, 112, 113, 114, 115, 116. M. KOBAYASHI* reported the locality of the same species from Fukushima Prefecture.

Family *Scopaenidae*

Genus *Sebastodes* GILL. 1816.

Sebastodes kanezawai, new species.

(Pl. III, 3; Pl. IV, 1-2.)

This species were found commonly from the lower fossil bed. The writer got three specimens well preserved.

Diagnosis:—Body oblong, mouth moderate, maxillary extending to a vertical through the posterior edge of opercle, snout equal to diameter of eye. Lower jow projecting, spines on the head unknown. Dorsal fin continuous through a shallow divide notch. The first spine and the 12th spine are very long, and 10th and 13th spines have the same length. The 2nd and the 3rd ray are very long. Anal fin rounded, the first spine is a little longer than one half of the longest spine, the 2nd and the 3rd spines are of equal length, the second much stronger. Pectral fin unknown. Ventral fine very small, one spine and five rays. The edge of the caudal fin slightly convex.

Vertebrae rather strong, number of vertebrae 27 (12+15). Scale invisible.

The measurement of the most complete specimen (Pl. III. Fig. 3) is as follows:—

Head 2.7 in length of body, depth 3.8, depth of caudal pedancle 2.3 in head, eye 3.3, snout 3.5, maxillary 1.8. Hight of the longest spin of dorsal fin 2.9 in head, longest ray 2.6, the first spine of anal fin 5.3 4, longest spine 2.5/9, longest ray 3.1/15.

Hight of the longest ray of ventral fin 3.5/6 in head, caudal 12.3/10.

Dorsal. XIII, 13; Anal III, 9; ventral I, 5 Pectral unknown.

(2) *Scomber japonicus* Hottouyn. Kishinoue: Jour. Coll. Agr. Imp. Univ. Tokyo. Vol. VIII, No. 3. pp. 403. Pl. XIX. Fig. 1. 1923.

(3) *Scomber colias* Gmelin. D. A. Jordan and B. W. Everman: Bull. U. S. A. Nat. Mus. No. 47. pp. 866. 1896.

* *Scomber* sp. M. Kobayashi: Proc. Paloeont. Soc. Japan. No. 10. 1928.

Remark:—This fish closely resembles a young specimen of *Sebastodes inermis* CUVIER & VALENCIENNES[4] or *Sebastodes schlegelii* HILGENDORF[5] Those species are distributed from Hokkaido to Kyûshû, but rarely found in the southern region.

Measurement on three specimens of *Sebastodes kanezawai* new species.

Items	Reg. No. 117	Reg. No. 118	Reg. No. 119
Total length	7.4cm.	12.6cm.	7.5 cm.
Length of body	6.3	10.6	6.2
Length of head	2.0	3.8	2.3
Length of upper maxillary	1.3	2.7	1.3
Length of lower maxillary	—	1.8	1.1
Length of orbital sinus	0.65	1.5	0.7
Length of snout	0.5	1.4	0.65
Depth of body	1.9	3.5	1.6
Length of caudal pedancle	1.1	1.8	1.3
Depth of head	1.55	3.1	1.35
Number of vertebrae	27	21	27
Number of dorsal fin	XIII, 12	XIII, 12	XIII, 12
Length of the longest spine in dorsal fin	0.7	—	0.8
Length of the longest ray in dorsal fin	0.75	1.3	0.75
Number of ventral fin	I.5	—	I.5
Length of the longest ray in ventral fin	0.8	—	0.6
Number of anal fin	III, 9	III, 7	III, 7
Length of anal spine	—	1.6	0.9
Length of the longest ray in anal sp. fin	—	1.6	0.75

Locality:—Lower fossil bed, Orita, Sawada-Mura, Azuma-Gun, Gunma Prefecture. Reg. Nos. 117, 118,* 119.* (*No specimen, after war.)

Family *Pleuronectidae*

Genus *Protopsetta* SCHUMIDT 1904.

Protopsetta kubotai new species
(Pl. V. 1)

This specimen is an impression of blind side of fish on tuffaceous shale. The ventral region and anterior part of anal fin are not preserved.

Diagnosis:—Head 3.4 in length of body; depth 2.1; Orbit 5.7 in head, maxillary 1.4, snout 2.7, length of caudal pedancle 4.2; number of vertebrae 41

(4) *Sebastodes inermis* (Cuvier and Valenciennus.) Jordan and Starks: Proc. U. S. A. Nat. Mus. Vol. XXVI, No. 1351. pp. 103.

(5) *Sebastodes schlegelii* (Hilgendorf). D. Jordan and S. Tanaka: Jour. Coll. Sci. Tokyo Univ. Vol. XXXIII, Art. 1. pp. 232. 1913.

(10+31), vertebrae runs upper 1/3 of body. Upper eye places on the upper margin of head.

Dorsal fin with 69 rays, Anal 47 (anterior part is broken).

Mouth large, lower jow projecting a little than lower jow. Length of maxillary about 1/3 that of head, posterior edge attaining under the middle part of orbital sinus. Teeth small, conical; Scale invisible.

Remark:—This species is allied to *Protopsetta herzensterni*[6] (SCHMIDT), but this fossil fish having large number of verebrae which run on the upper part of the body.

Measurement.

Items	Reg. No. 120
Total length	20.5 cm.
Body length	17.2
Depth of body	8.2
Length of head	5.2
Length of snout	1.9
Length of orbital sinus	0.9
Length of upper maxillary	2.9
Length of lower maxillary	2.3
Depth of head	3.0
Length of the longest dorsal fin	2.1
Length of anal fin	1.8
Depth of caudal fin	5.0
Length of caudal pedancle	1.2
Depth of caudal pedancle	1.7

Locality:—Lower fossil bed, Orita, Sawada-Mura, Azuma-Gun, Gunma prefecture.

Reg. No. 120.* (* No specimen, after war)

Family *Blenniidae*

Genus *Stichaeus* Reinhardt 1837

Stichaeus matsubarai new species.

(Pl. V. 2; Pl. VI. 2.)

The specimens of this species obtained from the lower fossil bed, which are two perfect fossils and fragmental one.

(6) *Protopsetta herzensterni* (Schumidt), D. S. Jordan and E. C. Starks: Proc. U.S.A. Nat. Mus. Vol. XXX. pp. 194, 1907.

Diagnosis: -Body elongated, scale not visible, number of vertebrae 52 (11+41) or more, depth of body 5.2 in length of body, depth of caudal pedancle 1.3. Dorsal fin slender and consist of stiff spine more than 33 in number, inserted above gill opening, not united to caudal fin. Anal fin consists of soft rays, beginning just under the 20th dorsal spine, not united to caudal fin. Ventral fin pointed, 0.75 in body length except head.

Remark: —This fish closely resembles *Stichaeus nozawai*[7] JORDAN and SYNIDER which is distributed in the northern sea around Japan.

Locality:—Lower fossil bed, Orita, Sawada-Mura, Azuma-Gun, Gunma prefecture. Reg. No. 221, 122* (*No specimen after war)

Measurement

Items	Reg. No. 121	Reg. No. 122	Fragment
Body length	6.25cm.	6.5cm.	—
Depth of body	1.2	1.6	—
Depth of caudal pedancle	0.4	0.5	—
Length of eye	0.65	—	0.69
Length of head	1.45	—	2.7
Length of snout	—	—	0.5
Length of orbital sinus	—	—	0.15
Length of caudal fin	0.4	1.1	—
Length of ventral fin	1.7	—	—
Number of vertebrae	52	42	—
Number of dorsal spine	42+	45	—
Number of anal fin ray	25	1.34	

Crustacea

Tribe Eucyphidea

Family *Pandalidae*

Genus *Pandalus* LEACH 1814

Pandalus oritaensis new species.

(Pl. VI. 2, Pl. VII. 1.)

The fossil prawns are commonly found in the concretion from the lower fossil bed at Orita, Sawada-Mura, Azuma-Gun, Gunma Prefecture. But it is very difficult to get a perfect specimen on which appoint the name of species.

The writer obtained two specimens available for the description set forth below, one without rostrum and another without most bodyly parts except calapace.

(7) *Stichaeus nozawae* Jordan and Snyder. Jordan and Snyder: Proc. U. S. A. Nat. Mus. Vol. XXV. No. 1293. pp. 496. 1902.

Diagnosis:—Body rather robust, rostrum about 1.4 times as log as calapace. Median crest of calapace extending posteriorly as an obtuse ridge to near the posterior margin. The median crest anteriorly armed with 5 spines; the first spine is inserted at a position 1.4 mm posterior to the anterior margin of calapace. The longest spine measures 1 mm in length.

The posterior half of the rostrum a little deflex, anterior acending, tip near terminated in the same level of calapace. Orbital sinus large and broad. Antenual scale large and broad. Legs are longer than calapace about 2.1/5 times as long as calapace. Among seven abdominal sommites, five ones are well defined as five swiming legs attached to each of the somite. The pleura of the second somite overlap on the first and the third pleura.

Remark:—According to the characteristics above mentioned, this fossil prawn closely resembles *Pandalus nipponensis* YOKOYA[8] which is distributed in the deep sea around Japan, but easily assortable from the species newly established in the configulation of rostrum.

Measurements

Items	Reg. No. 123	Reg. No. 124
Total length of specimen	9.5 cm.	8.5 cm.
Length of thorax	3.6	4.8
Length of calapace	2.4	2.2
Length of rostrum	—	2.9
Depth of calapace	1.9	1.7
Length of abdomen	4.1	4.0
Length of uropod	1.25	—
Width of uropod	0.4	—
Length of tailson	1.3	—
Length of tailson	1.0	—
Length of the 5th leg.	4.3	—
Length of the 4th leg.	4.3	—
Length of the 3th leg.	5.4	—

Locality:—Lower fossil bed at Orita, Sawada-Mura, Azuma-Gun, Gunma Prefecture. Reg. No. 123*. (* No specimen, after war), 124.

III. THE FOSSIL FISH FROM TOTTORI PREFECTURE

Four fragmental specimens of the fossil fish were placed in the collection of the Imperial Fisheries Institute. Those specimens were collected from Ueno Mura, Iwami-Gun, Tottori Prefecture by the late Mr. T. IGAKURA of the Tottori

(8) *Pandalus nipponensis* Yokoya. Yokoya: Jonr. Coll. Agr. Tokyo. Imp. Univ. Vol. XII. No. 1. pp. 16. 1933.

Normal School who sent the fossils for the writer's study. The preservation of the fossils is not so good, but among them, the largest one is comparatively well preserved and well fitted for determination of its species. The following description is based on this specimen.

1. Stratigraphic note

The fossil is an impression in reddish grey thin laminated siliceous shale in which broad reef plant fossils are contained.

An examination of a thin section of the rock under the microscope shows that there are numerous fossil marine diatoms belonging to the species *Cossinodiscus radialus* EHR. Which is distributed in the Tertiary deposit of San'in district, also living in the Sea of Japan. According to the graduation thesis of Mr. H. TANAKA, Geological College of Tohoku Imperial University, the geological horizon of the fossil bed is involved in the *Comptoniphyllum* horizon (lower Neogene Tertiary) at Iwami Gun, Sanin district.

2. Description of species

Pisces
Series Teleostei
Order Isospondyli
Family *Clupeidae*
Genus *Iquius* JORDAN 1919

Iquius subnipponensis, new species.
(Pl. VII. 2.)

Diagnosis:—Head 14 in depth at the front of dorsal fin; eye 2.8 in head; hight of dorsal fin 2.0 in head; length of pectral 0.8; length of ventral 0.8. Dorsal fin II, 7; pectral 16; venfral 7

Vertebrae in front dorsal fin 13; to first spinal 10; to first inter hemal 21; total more than 41 (perhaps 39, observed from other specimens).

Occipital region rather depressed, the nape rising moderately behind it; snout apparently short. Mouth small, eye large, opercular bone entire; preopercule narrow, opercule very broad. The vertedrae small about deep as long, neural spine straight, rather weak, directed backward; dorsal interspinal rather strong; the anterior one especially, ribs moderate, curved, not directed hackward.

Dorsal fin short, rather high with a large spine or ray with seration and a small depressed ray or spine in front of it which is about half of the third ray. The rays follow behind the third ray are very short and the last one is

about one third of the third. The pectral fin inserted below, lower ray much weaker than upper. Ventral fin pointed about under the first dorsal spine, and rays are rather strong.

Scale invisible or scarsely impressed in dorsal part; they are thin and cycloidal shape.

Remark:—As the fossil fish is not well preserved and fragmental, the determination of species is very difficult. But the general appearance closely resemdles that of *Cyprinoidae* in short dorsal fin with a simple pressed ray in front as in most Cyprinidae, especially to the living species *Ishikauia steenackeri*[9] (SAUVAGE). There is another analogous fossil fish species known in

Measurement

Items	Reg. No. 125
Total length	140 mm.
Length between snout and the first dorsal fin	80
Depth of body at front of dorsal fin	56
Length of head	40
Depth of head	35
Length of orbital sinus	14
Length of dorsal fin	20
Length of pectral fin	31
Number of dorsal fin	II(?), 7
Number of pectral fin	16
Number of ventral fin	7
Number of vertebrae to front dorsal	13
Number of vertebrae to first inter spinal	10
Number of verterae to first inter hemal	21
Total number of vertebrae (some unknown)	31
Width at the base of dorsal fin	18
Width at the base of pectral fin	8
Width at the base of ventral fin	5

Japan. In 1919 Dr. David Starr JORDAN reported a new fossil fish "*Iquius nipponensis*"[10] from the Tertiary deposit of Iki Island, Nagasaki Prefecture, Japan. *Iquius nipponensis* closely resemble in the character of fin, shape of head, vertebrae, but there are some difference.

In this fossil the numbers of vertebrae are a little more, numbers of spine or ray are more than that of *Iquius*, and the spine is more strong, vent-

(9) *Ishikauia steenackeri* (Sauvage): D. S. Jordan and H. W. Fowler. Proc. U. S. A. Nat Mus. Vol. XXVI, pp. 857. 1902.

(10) *Iquius nipponensis* Jordan. D. S. Jordan: Proc. California Acad. Sci. Four. Ser. Vol. IX, No. 9. pp. 271. 1919.

ral fin inserted a little more ahead than *Iquius nipponensis* JORDAN.

According to the description on the character of *Iquius nipponensis*, Dr. Jordan enumerated the resemblances of the fossil fish both to *Cyprinidae* and *Culpeidae*, and said "I place the genus of fossil fish provisionally among *Clupedae*." Whether the situation in the classification of Jordan's fossil fish may be, the characteristics of the fossil fishes from Tottori Prefecture closely resemble the fossil fish descrived by Jordan as genus *Iquius*", so that the writer takes the genus name "*Iquius*" in this paper.

PL. I.

Somber nomurai new species.

Fig. 1. Left lateral view of body.—Upper fossil bed. Reg. No. 111.

Fig. 2. Right lateral view of posterior half of body.—Upper fossil bed. Reg. No. 112.

PL. I.

Fig. 1.

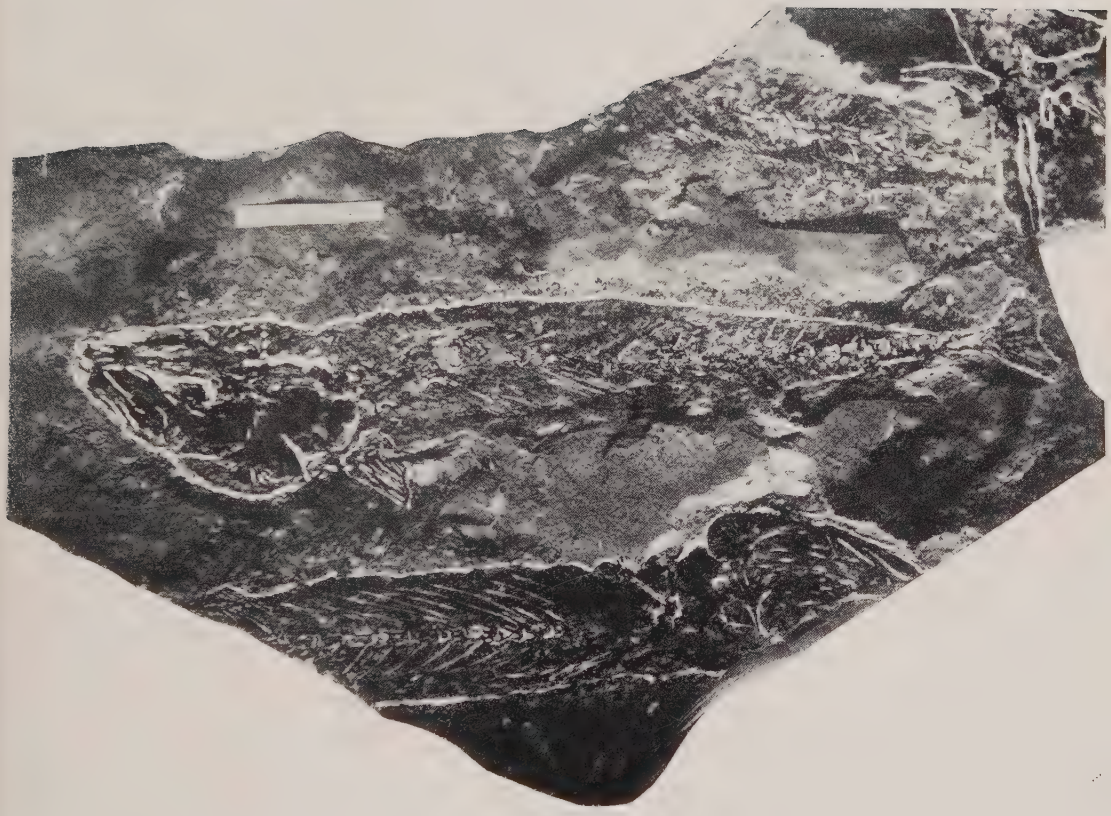
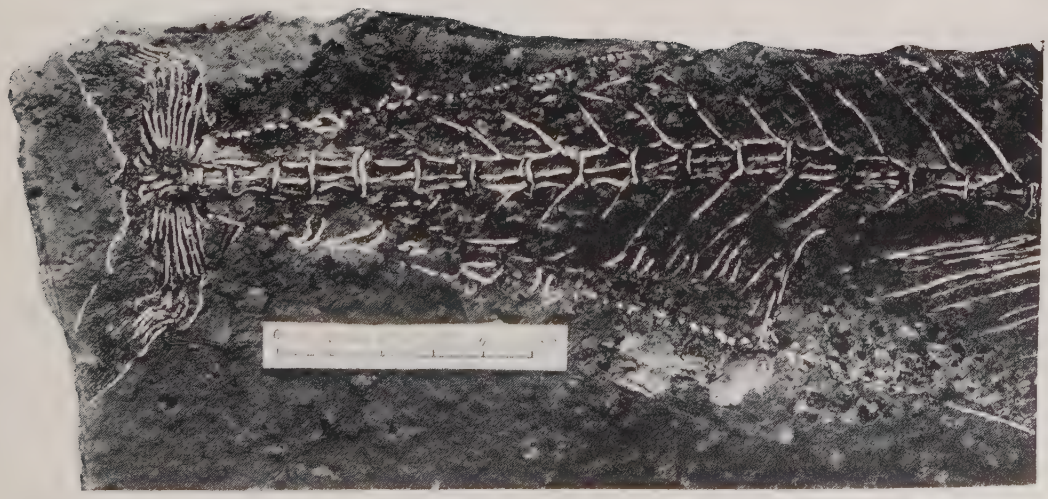


Fig. 2.



PL. II.

Scomber nomurai new species.

Fig. 1. Left lateral view of anterior half of body.—Upper fossil bed. Reg. No. 113.

Fig. 2. Right lateral view of posterior half of body.—Upper fossil bed. Reg. No. 114.

PL. II.

Fig. 1.

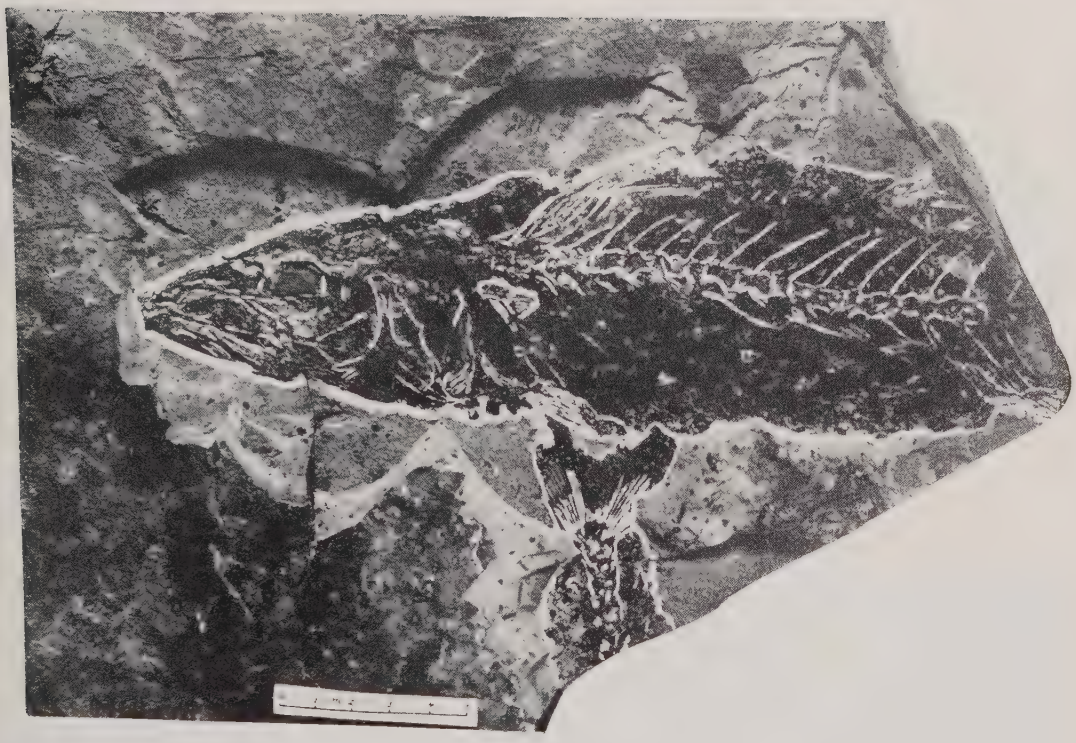


Fig. 2.

PL. III.

Scomber nomurai new species.

Fig. 1. Right lateral view of body.—Upper fossil bed. Reg. No. 115.

Fig. 2. Right lateral view of a body and left lateral view of a body, Both without head.—Upper fossil bed. Reg. No. 116.

Sebastodes kanezawai new species.

Fig. 3. Right lateral view of body.—Lower fossil bed. Reg. No. 117.

PL. III.

Fig. 1.

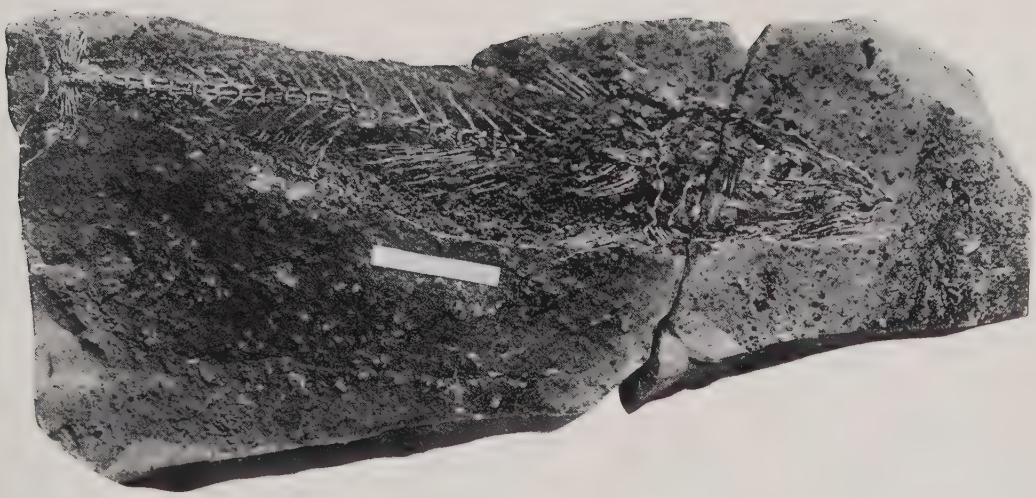


Fig. 2.

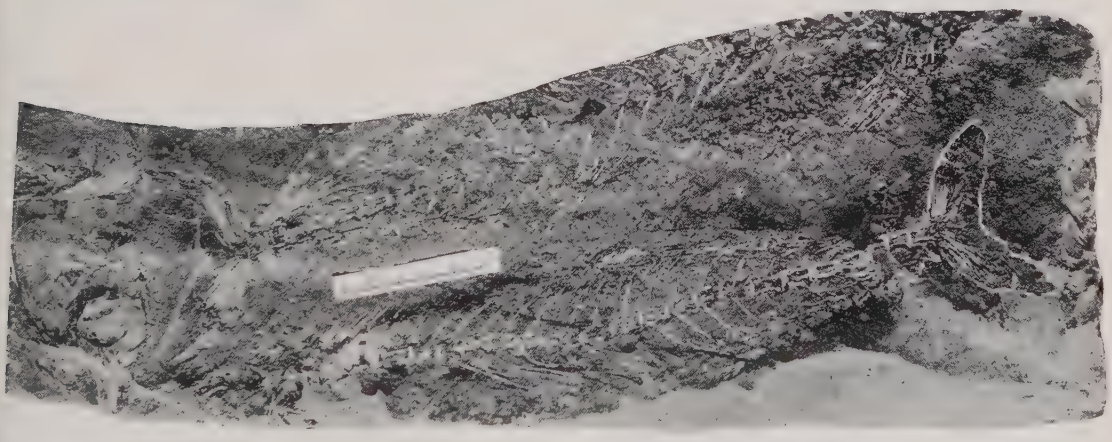
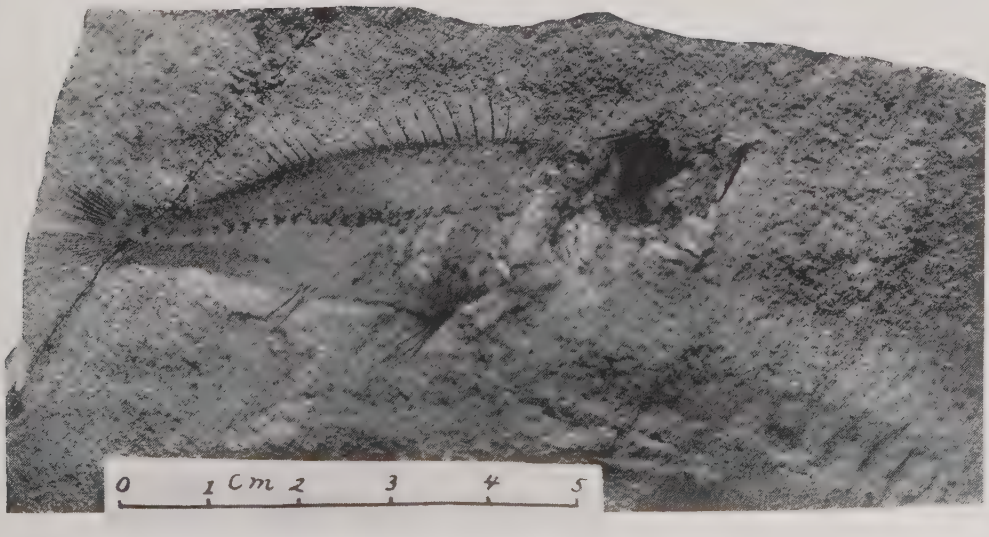


Fig. 3.



PL. IV.

Scbastodes kanezawai new species.

Fig. 1. Left lateral view of body.—Lower fossil bed. Reg. No. 118. (Loss by war)

Fig. 2. Right lateral view of body.—Lower fossil bed. Reg. No. 119. (Loss by war)

PL. IV.

Fig. 1.

Fig. .2

PL. V.

Protopsetta kuboiai new species.

Fig. 1. Left lateral view of body.—Lower fossil bed. Reg. No. 120. (Loss by war)

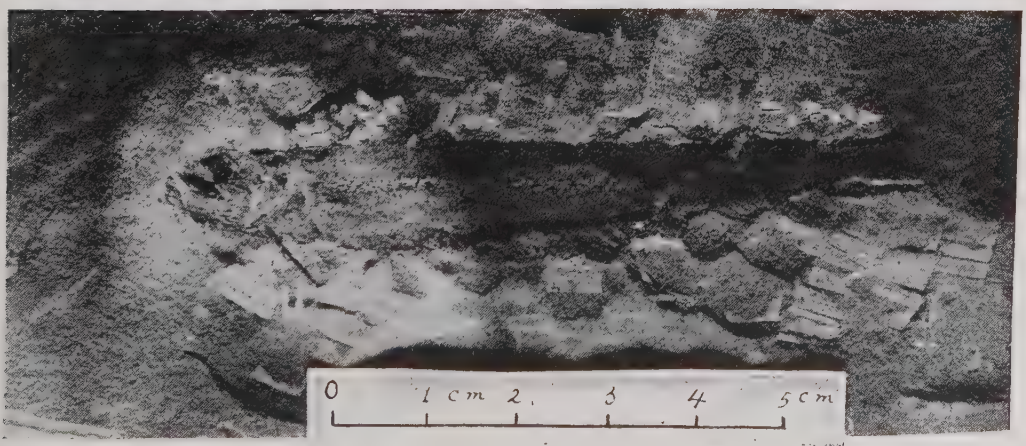
Stichaeus matsubarai new species.

Fig. 2. Lett lateral view of body.—Lower fossil bed. Reg. No. 121. (Loss by war)

PL. V.

Fig. 1.

Fig. 2.



PL. VI.

Stichaeus matsubarai new species.

Fig. 1. Left lateral view of body.—Lower fossil bed. Reg. No. 122. (Loss by war)

Pandalus oritaensis new species.

Fig. 2. Left lateral view of body.—Lower fossil bed. Reg. No. 123. (Loss by war)

PL. VI.

Fig. 1.

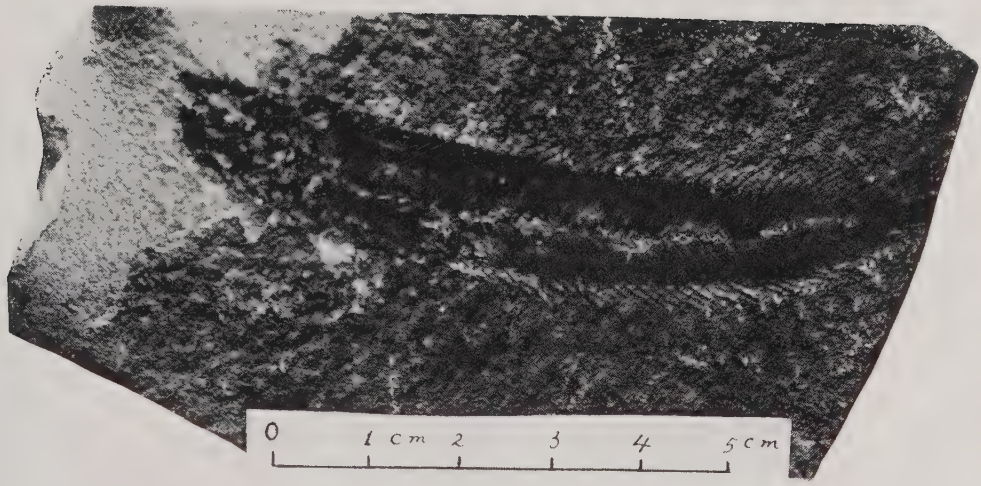


Fig. 2.

PL. VII.

Pandalus oritaensis new species.

Fig. 1. Calapace of *Pandalus oritaensis* new species.—Lower fossil bed. Reg. No. 124.

Iquius subnipponensis new species.

Fig. 2. Right lateral view of body without caudal region.—Ueno-Mura, Iwami-Gun, Tottori Prefecture. Reg. No. 125.

PL. VII.

Fig. 1.

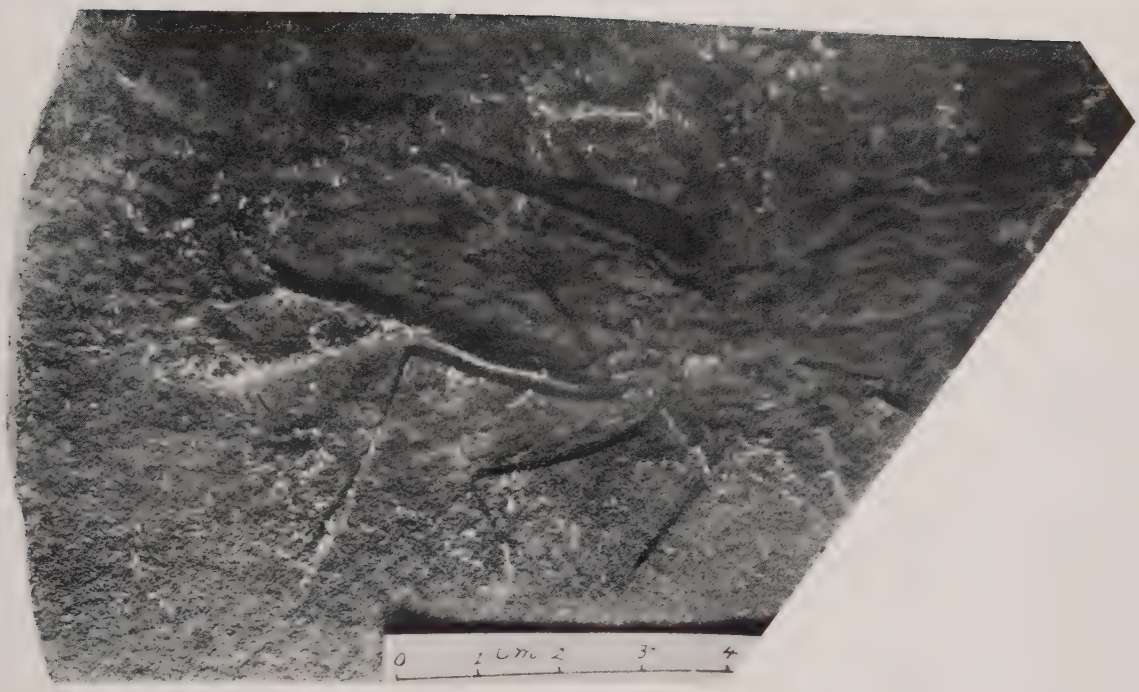


Fig. 2.

PRELIMINARY REPORT ON THE FISHMEAT-FRESHNESS MEASURING BY THE OSCILLATION METHOD

Sachio HOTANI

I INTRODUCTION

There are many reports on the variations of the physical nature at the time when the fishmeat-freshness falls. The writer has confirmed by the ordinary damping oscillation method that the internal friction of fishmeat varies with the lapse of time, and so reports the results.

Generally the equation of damping oscillation is represented as follows:-

$$M\frac{d^2x}{dt^2}+2\varepsilon\frac{dx}{dt}+kx=0$$

here M: mass. ε: resistance proportional to velocity.

x : displacement.

t : time. k: degree of stability.

This solution is

$$x=Ae^{-\lambda t}\cos(\sqrt{n^2-\lambda^2}\,t+\alpha)$$

here

$$\lambda=\frac{\varepsilon}{M} \qquad n^2=\frac{k}{M} \qquad \alpha: \text{phase}$$

So, when the state of internal friction and ε change, necessarily the damping state of oscillation must vary. And as the time elapes the protein is decomposed into lower compounds by autolysis and bacteria action, and the meat is softened. Accordingly the internal friction varies, and the variation appears to be corresponding to the freshness of the meat examined.

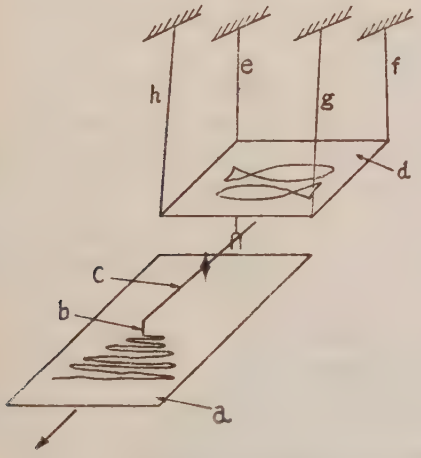


Fig. 1. a, Sooted paper (Moves in the same speed); b, Recording needle; c, Lever; d, Oscillating plate; e, f, g, h Suspender.

II THE METHOD OF EXPERIMENT

Laying down the fishes on the oscillating plate as shown in the Fig. 1, oscillate the plate free from side to side, and automatically record the damping state on the sooted paper which moves mechanically in the uniform speed in the direction at right angles

to the oscillation. To prevent the irregular oscillation and the decrease of mass by vaporising, two fishes are laid down on the centre of a plate in the direction opposite each other enveloped tightly in a hydrochloric acid rubber bag. Then damping ratio was calculated from the damping curve obtained in consideration of mechanical resistances of a recording needle nib, etc.

III RESULT

1) Carp: Experiments have done using two carps which were killed by cutting off their after-brain immediately before the experiments. The body -length and others of the specimens used are given in the following table.

	Body length (standard) (cm)	Body weight (g)	Body height (cm)
1	13.6	67.0	4.4
2	14.0	61.0	4.2

Doing experiments in every moderate time at room temperature, the damping curve was taken, and the damping ratio was calculated. On the other hand, amount of volatile basic nitrogen was measured on the other samples that were left in the same state as those emploied to the experiments taken damping curve. The result is given in the Fig. 2.

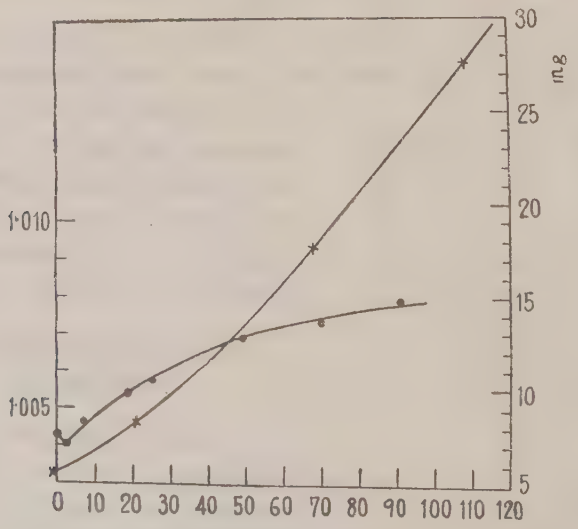


Fig. 2. Showing relation betwen time (h) (sbscissa) and damping ratio (ordinate, left), and that between time and volatile basic nitrogen as ammonia mg % (ordinate, right). Experiments were carried out at the room temperature 19°C on average.

2) **Sardine:** Experiments were carried out dealing with freezed sardines, 12. 4–12.6 cm long as put on the following table, obtained from a fishmarket. Of the fishes, the time elapsed after the catch of those and the management processes were unkown. But the freshness of them appears to be considerably low judging from ammonia contained within the meats of the fishes. The result taken from the experiments is given in the Fig. 3.

	Body length (standard) (cm)	Body weight (g)
1	12.6	33.2
2	12.4	31.6

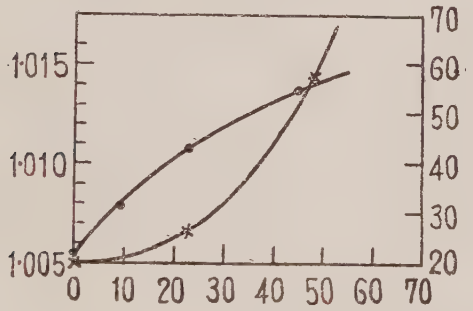


Fig. 3. The same as the Fig. 2. Experiments were carried out at the room temperature 9. 5°C on average.

IV CONCLUSION

From the experimets III, we can see the fact that the internal friction increases according to the fall of freshness, but this fresheness which is expressed by oscillation method is different in its temper from that expressed by amount of volatile basic nitrogen. In the present study the period of oscilliation is 2 seconds at the beginning of the experiment. But further experiments changing the initial oscillation period may be undertaken in future to analyse the relevance between the period and damping state.

Finally the author tenders hearty thanks to Mr. M. IGARASHI (Yokosuka Cold Strage Co. Ltd.) and Mr. K. KONNO (Piscicultural course of the Tokyo University of Fisheries) who offered the samples on which the present experiments have done.

ON THE STRENGTH OF THE NETTING CORD AGAINST A SINGLE BLOW (1)

Katsuji HONDA

Formerly, Dr. M. TAUCHI[1] indicated that energy necessary for fracture netting cord decrease in accordance with increasing of impact velocity and weight of acting body by which impulsive force is occured on his repeated blow test with Cotton, Japanese hemp, Ramie and Manila hemp netting cord. And SHIMIZU,[2] studying the strength of the cotton netting cord against a single blow, indicated that energy necessary for cutting it is almost constant whatever impact velocity and weight of acting body is applied. By those facts given above, it appears to be not difficult that energy which will be consumed at the time when netting cord is cut by a single blow, has relation to the impact velocity and weight of acting body. To treat this problem, the writer has analysed the available data obtained from the impact test of netting cords handling the same apparatus used by SHIMIZU afore mentioned by the students of this faculty during the years from 1936–'44. The preliminary report of the results may be set forth on the Bulletine of the Japanese Society of Scientific Fisheries, vol. 16, and the detailed one are given in the following lines.

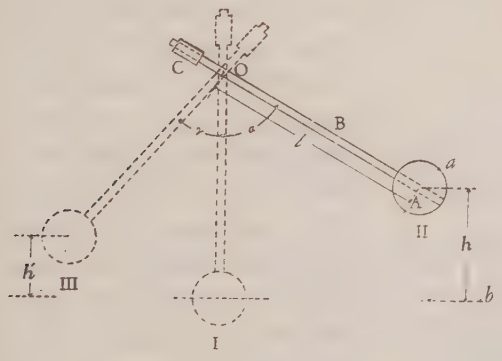


Fig. 1. Schematic showing of the Apparatus used for the present experiment. A, changeable weight; B, arm of pendulum; C, counter of weight; O, axis of rotation. a, b, chuck.

The method of the measurement of values used in this article is demonstrated graphically in the Fig. 1. The sample of a length suitable for the experiment are fixed to the chuck (*a*) and the point (*b*) in each its end. The samples are fractured when the pendulum comes down to the point I. The angle α are the angle between the vertical axis of this apparatus and the arm of the pendulum lifted to the point II with a height h. The angle γ is that yield between the vertical axis and the arm of the same part of the apparatus when the pendulum goes up to a certain point III at height of h' after cutting the samples examined. The impact velocity v and energy necessary for fracture E can be denoted by the following expressions respectively:—

$$v=\sqrt{2gh}\,\frac{1}{\sqrt{1+\frac{I}{Wl^2}}}\quad,\quad E=Wl(\cos\gamma-\cos\alpha)$$

where g displays the acceleration of gravity, W weight of pendulum, I moment of inertia of point o on the rotation axis, l distance between rotation axis and centre of changable weight.

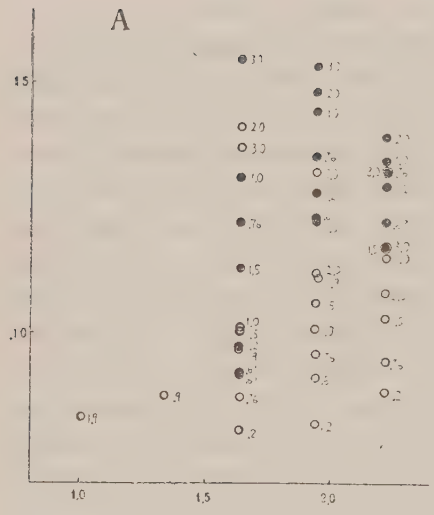
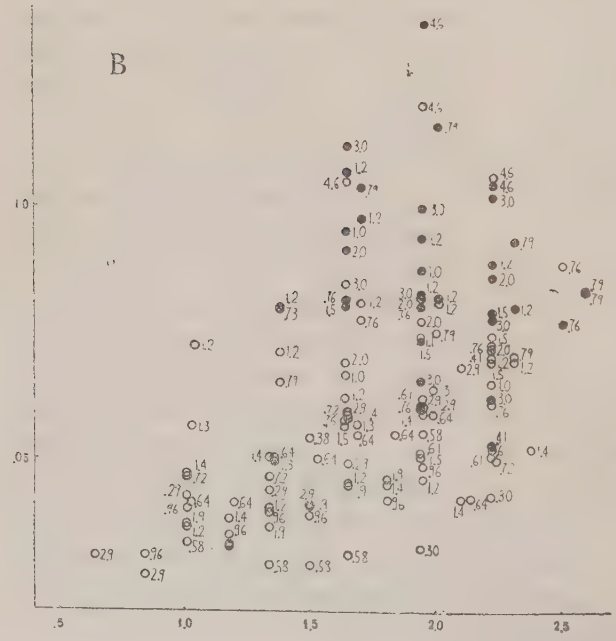


Table 1 shows the results of the observation made in the present inspection. Calculation of standard deviation was done when the data an item are enough to calculate it. Impact velocity v and energy necessary for fracture E were calculated by using above equations in the case of W and h respectively. The calculated values of v and E according to the each value given in Table 1 are amounted on the Table 2. From the Table 2, the values E/a and W/a were led. Where a is number of yarns in cotton and ramie, as well as the area of section (mm^2) in manila hemp netting cord. In Fig. 2, the values E/a and W/a are given in relation to v. On basing the Fig. 2 it may be concluded that E/a increases in accordance with ncreasing v and W/a, and more energy for fracturing is needed for the wet cord than the case of dried one. The value E/a increases in accordance with the values v and W/a. This



matter is probably considered that the time elasped during the collision decreases in accordance with v and W/a increase. However, the measurement of the impact time is no easy task. Therefore the further experiment of this problem may be performed in shortly later.

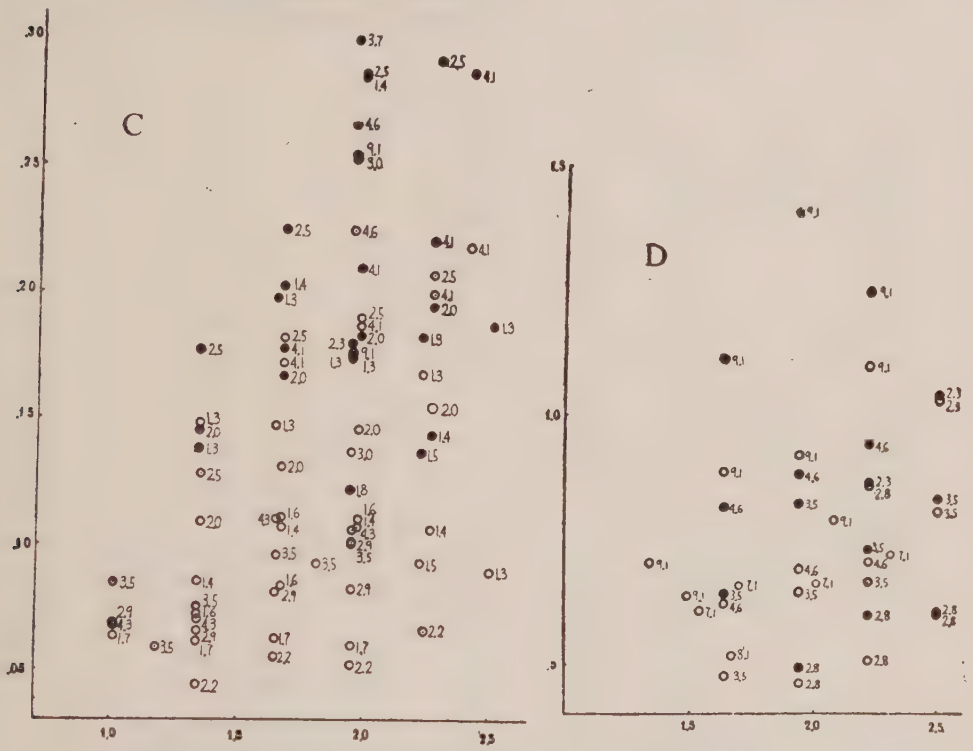


Fig. 2. Showing relation between v m/sec and E/a kg-m (Ordinate). A, Cotton 10's; B, Cotton 20's; C, Ramie 20's; D, Manila Hemp. Solid marks show values observed in wet. Soft ones values in dry. Numerals associated with marks shows the value of W/a.

Finally, the writer should like to state his hearty thanks to Professor Dr. M. Tauchi who has looked over this thesis and also to Professor K. Miyoshi who has given a good advice for the present investigation.

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1. TAUCHI, M. 1927. A study on netting cords I. The study of the netting cord against the repeated blow. (1). Jour. Imp. Inst., 23 (1), pp. 26–30.
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STUDIES ON THE PICKLING INHIBITOR

(PRELIMINARY REPORT)

Junsaku NONAKA

In the hot working and heat treating of iron and steel, a scale is formed on the surface which it is often necessary to remove before the iron may be used. Pickling, in a dilute acid bath, is the usual method of removing this scale. In this pickling bath both the scale and the base metal from which the scale is being removed, are attacked by the acid. The solution of the base metal, in most cases, causes an economic loss both in metal and in acid. Furthermore, the hydrogen evolved resulted from the attack on the iron is responsible for the formation of blisters, the embrittlement of the iron, and the spraying of sulfuric acid fumes into the air. Because of these several objectionable features of ordinary acid pickling, inhibitors have come into use to prevent or materially to retard the dissolution of metallic iron.

Many substances act as inhibitors; among others dextrine, gelatine, glue, molasses, crude anthracene, sulfite lye, residues from the production of naphthalene, substances formed by the hydrolytic decomposition of proteins and containing -COOH-, -CHO, -OH, $-NH_2$ and -S- radicals, pyridine, quninoline and its derivertives, flour, sulfonated oils, tannin, furfurol, $Al_2(SO_4)_3$ and others.

The use of inhibitors in pickling iron preliminary to tin plating must be watched very carefully. In some cases no detrimental effects have been observed while in others the inhibitor has been found to be definitely harmful. Inhibitors are of real value if used with through knowledge.

The present author has undertook an investigation on the inhibitive action of several thiourea derivatives and two kinds of inhibitors which are now used by some of the tin-plate makers in our country.

EXPERIMENTAL

A) Iron sheet used:

An ordinary low carbon black sheet is cut 1″ by 2″ in size and the both sides of it are polished alternately lengthwise and breadthwise with the No. 0 emery paper, then washed with hot alcohol, and ether, and finally wiped up with a dry cotton cloth.

B) Inhibitors used:

Except the thiourea and the two kinds of inhibitors now used in this

country (Inhibitor A and Inhibitor B), other thiourea derivatives were synthesized by the auther according to the literature cited. They are as follows: a) Inhibitor A, b) Inhibitor B, c) Thiourea: Merck, extra pure, d) Diphenylthiourea[1], e) Di-o-Tolylthiourea[2], f) Di-m-Tolylthiourea[2], g) Di-p-Tolylthiourea[2], h) Di-m-Xylylthiourea[3], i) N-phenyl-N'-o-tolylthiourea[4], j) N-phenyl-N'-m-tolylthiourea[4], k) N-phenyl-N'-p-tolylthiourea[4], l) Phenylthiourea[5], m) o-Tolylthiourea[5], n) p-Tolylthiourea[5]

C) Method:

A measured weight of inhibitor is added to a 200cc. glass stoppered wide mouth reagent bottle containing 100cc. of 15% sulfuric acid solution and settled in a water bath which is adjusted to a temperature 75±5°C. A piece of black sheet is put into the acid solution, and after 30 minutes soakage without shaking, picked up with a bamboo pincette; and its surface is thoroughly washed with distilled water. Then the washings are added to the acid solution. The moisture on the surface of the test piece is then removed by alcohol and ether, and the surface conditions of thus pickled irons are observed two days after the pickling.

The quantities of the dissolved iron is either calculated directly according to the difference of the weight of the test piece before and after the pickling or those in the pickled solution are determind colorimetrically after the KCNS method.

D) Results obtained:

The relations between the quantities of the dissolved iron and of each inhibitors used are shown respectively in the following tables and figures, and the surface conditions of the test pieces which are pickled in an acid solution containing each inhibitors are observed as follows:

TABLE I. Inhibitor A

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□" of test piece
1	1	63.5
2	5	35.7
3	7.5	14.1
4	10	12.5
5	25	9.7
6	50	7.1
7	100	4.1
8	200	2.2

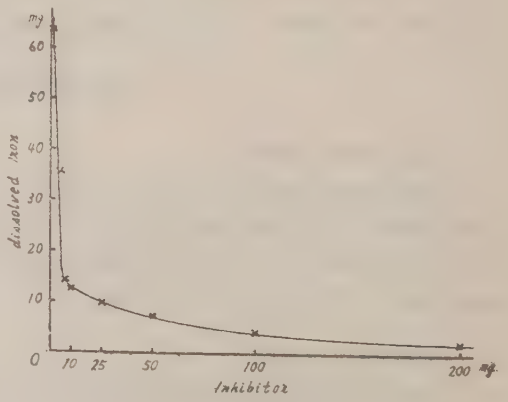

Fig. 1. Inhibitor A

a) Inhibitor A:

Partially soluble in water and 15% sulfuric acid solution. The surface of the test pieces No. 6, 7 and 8 had a metallic lustre but the others were covered with a black film.

b) Inhibitor B:

This is a dark colored liquid of strong acid solution, dispersable in water and 15% sulfuric acid solution. The surface of the all test pieces was discolored to black.

TABLE II. Inhibitor B

No.	Inhibitor mg. in 100cc of 15% H_2SO_4	Dissolved iron mg. per 4□" of test piece
1	1.1	99.3
2	5.4	55.3
3	10.8	29.2
4	54.1	16.4
5	108.2	29.3
6	216.3	26.7
7	——	——
8	——	——

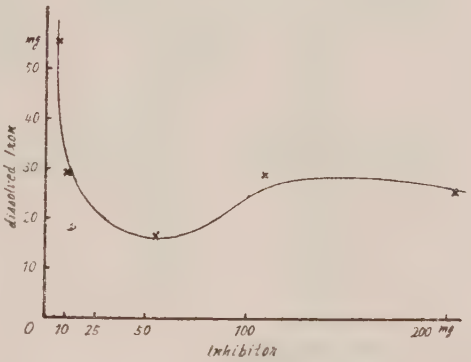

Fig. 2. Inhibitor B

c) Thiourea:

Soluble in water and 15% sulfuric acid solution. It seems that the nature of thiourea is very different from many other inhibitors, for this one is more effective in the small quantity than in the large quantity. The surface of the all test pieces was covered with a gray white film which is easily removed by rubbing.

TABLE III. Thiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□" of test piece
1	1.0	11.9
2	5.0	9.4
3	7.5	7.6
4	10.0	7.2
5	25.0	8.6
6	50.0	7.0
7	100.0	8.9
8	200.0	14.2

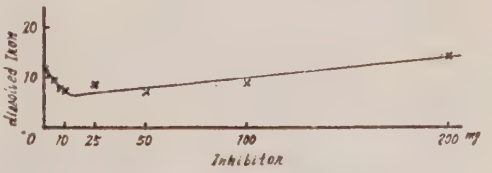

Fig. 3. Thiourea

d) Diphenylthiourea:

Insoluble in water and 15% sulfuric acid solution. Except the test pieces No. 1 and 2, the surfaces of the other test pieces had a metallic lustre.

TABLE IV. Diphenylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	107.6
2	5.0	14.9
3	10.0	5.0
4	25.0	2.7
5	50.0	2.5
6	75.0	2.6
7	100.0	2.4
8	200.0	2.0

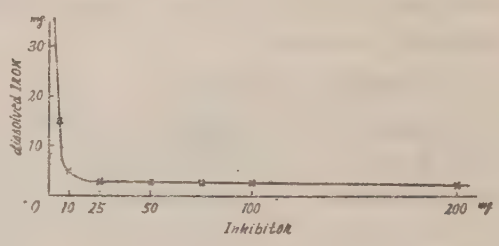

Fig. 4. Diphenylthiourea

e) Di-o-tolylthiourea:

Insoluble in water and 15% sulfuric acid solution. Except the No. 1, the other test pieces had a metallic lustre.

TABLE V.
Di-o-tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	10.9
2	5.0	8.4
3	10.0	4.0
4	50.0	2.0
5	100.0	1.7

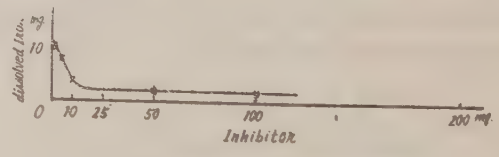

Fig. 5. Di-o-tolylthiourea

f) Di-m-tolylthiourea:

Insoluble in water and 15% sulfuric acid solution. The surface of the test pieces No. 5 and 6 had a metallic lustre, but the other was discolored to gray black.

TABLE VI.
Di-m-tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	96.1
2	5.0	56.7
3	10.0	40.1
4	50.0	12.9
5	100.0	7.0
6	175.0	5.8

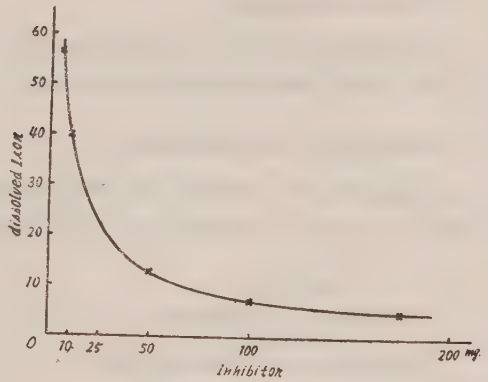

Fig. 6. Di-m-tolylthiourea

g) Di-p-tolylthiourea:

Insoluble in water and 15% sulfuric acid solution. The surface of the all test pieces was discolored to black.

TABLE VII.
Di-p-tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	57.7
2	5.0	42.6
3	7.5	39.2
4	10.0	19.6
5	25.0	20.2
6	50.0	14.8
7	100.0	11.8
8	200.0	21.0

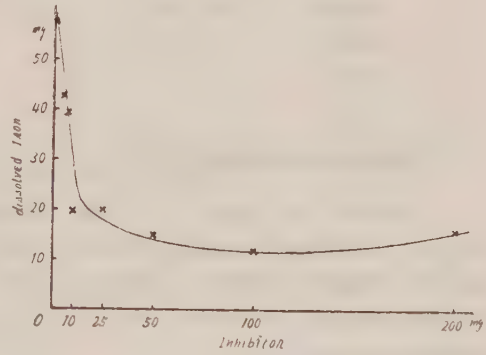

Fig. 7. Di-p-tolylthiourea

TABLE VIII.
Di-m-xylylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	143.3
2	2.0	46.5
3	5.0	49.8
4	10.0	26.2
5	50.0	28.7
6	100.0	20.4

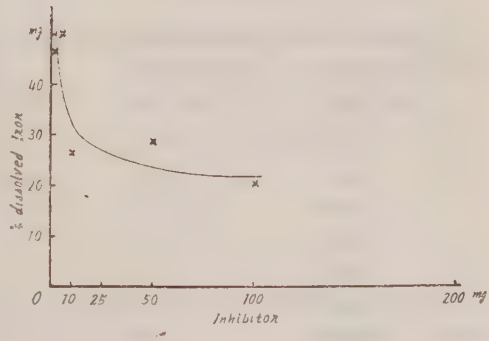

Fig. 8. Di-m-xylylthiourea

h) Di-m-xylylthiourea:

Insoluble in water and 15% sulfuric acid solution. The surface of the all test pieces was discolored to black.

i) N-phenyl-N′-o-tolylthiourea:

Insoluble in water and 15% sulfuric acid solution. Except the test pieces No. 1 and 2, the surface of the others had a metallic lustre.

TABLE IX.

N-phenyl-N′-o-tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	63.5
2	5.0	14.0
3	10.0	5.3
4	25.0	4.0
5	50.0	2.2
6	100.0	2.4
7	200.0	1.8

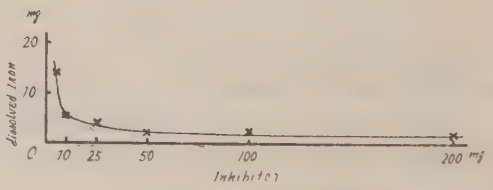

Fig. 9. N-phenyl-N′-o-tolylthiourea

j) N-phenyl-N′-m-tolylthiourea:

Insoluble in water and 15% sulfuric acid solution. The surface of the all test pieces had a metallic lustre, but on account of its low melting point and the lighter specific gravity than the pickling solution, the fused inhibitors are apt to cofere to the surface of the test piece and caused black discoloration on it.

TABLE X.

N-phenyl N′-m-tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	39.1
2	5.0	5.0
3	10.0	3.2
4	25.0	2.8
5	50.0	1.5
6	100.0	1.8
7	200.0	1.3

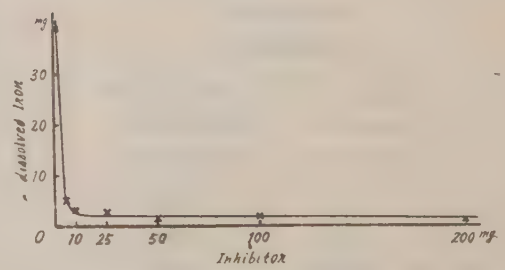

Fig. 10. N-phenyl-N′-m-tolylthiourea

k) N-phenyl-N′-p-tolylthiourea:

Insoluble in water and 15% sulfuric acid solution. Except the test piece No. 7, the surfaces of the others were discolored to gray black.

TABLE IX
N-phenyl-N′-p-tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	158.7
2	5.0	74.4
3	10.0	73.9
4	25.0	34.4
5	50.0	11.1
6	100.0	8.1
7	200.0	4.2

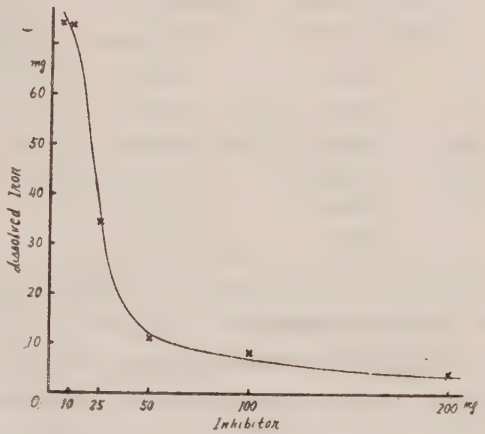

Fig. 11. N-phenyl-N′-p-tolylthiourea

l) Phenylthiourea:

Soluble in water and 15% sulfuric acid solution. Except the test piece No. 1, the surface of the others had a fine metallic lustre.

TABLE XII
Phenylthiourea

No.	Iohibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	24.9
2	5.0	4.9
3	10.0	2.2
4	25.0	1.4
5	50.0	1.1
6	100.0	0.65
7	200.0	0.66

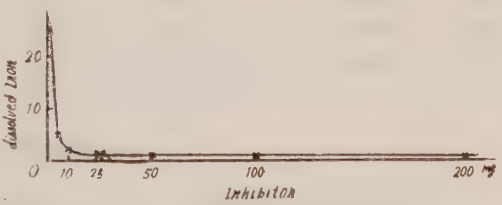

Fig. 12. Phenylthiourea

m) o-Tolylthiourea:

Soluble in water and 15% sulfuric acid solution. Though the quantity of the dissolved iron was comparatively small, the surface condition of the all test pieces is not so good.

TABLE XIII
o-Tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	3.8
2	5.0	4.1
3	10.0	1.5
4	25.0	2.4
5	50.0	1.9
6	100.0	2.7
7	200.0	3.6

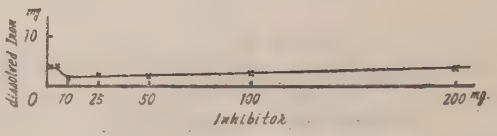

Fig. 13. o-Tolylthiourea

n) p-Tolylthiourea :

Soluble in water and 15% sulfuric acid solution. It seems that this inhibitor is an excellent one from every point of view.

TABLE XIV
p-Tolylthiourea

No.	Inhibitor mg. in 100cc. of 15% H_2SO_4	Dissolved iron mg. per 4□″ of test piece
1	1.0	12.7
2	5.0	3.5
3	10.0	2.5
4	25.0	1.5
5	50.0	1.5
6	100.0	1.9
7	200.0	2.7

Fig. 14. p-Tolylthiourea

DISCUSSION

1. The inhibitive effect of the tested inhibitors may be classified as follows:

A) Superior class.
Phenylthiourea, N-phenyl-N′-m-tolylthiourea, o-Tolylthoiurea, N-phenyl-N′-o-tolylthiourea, p-Tolylthiourea, o-Tolylthiourea, Diphenylthiourea.

B) Middle class.
Di-m-tolylthiourea, N-phenyl-N′-p-tolylthiourea, Thiourea, Inhibitor A.

C) Inferior class.
Di-p-tolylthiourea, Di-m-xylylthiourea, Inhibitor B.

2. The inhibitive effect of the di-Tolylthiourea is decreased in the order of ortho, meta and para.

3. The inhibitors of the type R-NH-CS-NH_2 (R is Aryl radical) are soluble in fifteen percent sulfuric acid solution and most of them are excellent even in the concentration of 15 mg per cent.

4. The relations between the inhibitor concentration and the inhibitive effect may be classified into the following three classes.

A) The inhibitors belonging to this class are Di-o-tolylthiourea, o-Tolylthiourea and p-Tolylthiourea. They are characterized by the inhibitive effect which is not remarkably influenced by the concentration of the inhibitor.

B) The inhibitors belonging to this class are Diphenylthiourea, Di-p-tolylthiourea, p-Tolylthiourea, N-phenyl-N'-o-tolylthiourea and N-phenyl-N'-m-tolylthiourea. The characteristics of them are that they produce very little inhibitive effect in the case of the small concentration but over a definite concentration the striking inhibitive effect.

C) The inhibitors belonging to this class are Di-m-tolylthiourea, Di-m-xylylthiourea, N-phenyl-N'-p-tolylthiourea and Inhibitor A. When in the small amount of these inhibitors no inhibitive effect can be observed, but in proportion to the concentration of the inhibitor the inhibitive effect becomes much stronger.

5. The inhibitors now used in our country can not be called a good one.

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2) FLEMMING, W.: United States Patent, 1,577,797.
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ON THE OSCILLATION OF WATER IN A CANAL GENERATED BY WIND ACTION

(Part 1)

Yasukazu Saito

ABSTRACT

The usual solution of equation of motion of a canal water generated by wind is mathematically true under the boundary condition that the component current normal to the vertical canal wall is zero along the coast, only when the tractive force of wind is zero at the coast, when the tractive force of wind is uniform all over the canal surface, the solution is not correct under any boundary condition.

In the present paper, the author treats the problem of this latter case. He transforms the usual equation into that containing the total flow S. In this case, the order of the differential equation coincides with the number of boundary conditions, so a solution of the equation can be obtained.

The obtained results is as follows:

$$\zeta=-\frac{4}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi}{a}x}{\sigma_n}\int_0^t T(\tau)\,e^{-f(t-\tau)}\sin\sigma_n(t-\tau)\,d\tau.$$

$$|\zeta|_{x=0}=-|\zeta|_{x=a}\quad,\quad |\zeta|_{x=\frac{a}{2}}=0$$

where ζ=the surface elevation or depression from the mean water level

T=the tractive force of the wind per unit area of the canal surface, and it is uniform for $0<x<a$

$\left.\begin{matrix}x=0\\x=a\end{matrix}\right\}$=both coasts of the canal

$$\sigma_n=\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}$$

$c=\sqrt{gh}$

h=the depth of the canal

f=constant number

Lastly the author investigates the case of the ressonance effect.

§ 1. INTRODUCTION.

The equation of motion in an irrotational canal generated by wind has

been already solved by Proudman and Doodson, Defant and others. Their solutions have been obtained under the boundary conditions that the horizontal current vanishes along the coasts, provided the tractive force of the wind is zero at these coasts.

But when the tractive force of the wind is uniform all over the sea surface, we cannot expect the solution to be correct mathematically under the given conditions. Because, in this case, the order of the differential equation of motion does not coincide with the number of boundary conditions. Namely, even if we expand the current velocity into Fourier's sine series, it is doubtful whether or not we can make the current velocity zero at the both sides of the canal. (This problem is connected with the uniform convergence of Fourier's series.)

To avoid this defect, Dr. Takegami succeded in obtaining a complete analytical solution for the steady state, taking the terms of horizontal and vertical austaushe into account, simultaneously.

Afterward, Prof. K. Hidaka gave a solution for the steady state by numerical calculations, taking the terms of the horizontal and vertical austaushe, and moreover the enertia terms into account. In the present paper, the writer deals with the same problem of the transient state in the cases of the constant as well as the varying wind. He obtains the surface elevation of sea water by transforming the equation of motion containing only one term of vertical austaushe as a frictional force into that of total flow, has making the order of the differential equation coincide with the number of boundery conditions.

But, with this method, it is naturally not able to obtain the current velocity itself, and moreover, the applicability of this method is restricted to either of the following cases:

(1) the case of no bottom friction, or

(2) the case of a finite bottom friction depending on the slip velocity.

§ 2. THE DIFFERENTIAL EQUATION OF TOTAL FLOW

First consider a canal of uniform depth limited by two infinite parallel strait coasts by a distance apart and suppose that a constant wind suddenly begins to blow over the surface initially at rest. Choose coordinates such that the z-axis is directed verticallry upwards and x-axis lies on the undisturbed level and perpendiculary to the coast, and x is measured from coast to coast, and denote the elevation of the free surface by ζ.

The other notations are as follows:

t=the time,

T=the tractive force of wind per unit area of the surface,
h=the depth of canal,
ρ=the density of water which is here assumed to be unity,
μ=the coefficient of eddy viscosity of water,
u=the velocity of current in the direction of x,
k=the coefficient of fliction at the bottom, asumming the resistance proportional to the slip velocity,
$\underline{u}$=the bottom current velocity of canal.

Then we have the equation of motion

$$\frac{\partial u}{\partial t}=-g\frac{\partial \zeta}{\partial x}+\mu\frac{\partial^2 u}{\partial z^2} \quad \cdots\cdots(1)$$

with the equation of continuity

$$\frac{\partial \zeta}{\partial t}=-\frac{\partial}{\partial x}\int_{-h}^{0} u dz \quad \cdots\cdots(2)$$

and the initial and boundary conditions:

$$u=0, \quad \zeta=0 \qquad \text{when} \quad t=0 \quad \cdots\cdots(3)$$

$$\mu\frac{\partial u}{\partial z}=T \qquad \text{at} \quad z=0 \quad \cdots\cdots(4)$$

$$\mu\frac{\partial u}{\partial z}=k\underline{u} \qquad \text{at} \quad z=-h \quad \cdots\cdots(5)$$

Now integrate (1) with respect to z from $-h$ to 0, and taking account of eq. (4), (5), we have

$$\frac{\partial S}{\partial t}=-gh\frac{\partial \zeta}{\partial x}+T-k\underline{u} \quad \cdots\cdots(1')$$

where $$S=\int_{-h}^{0} u dz \quad \cdots\cdots(6)$$

represents the total flow along the x-axis. By using the total flow S, the equation of continuity (2) may be written as

$$\frac{\partial \zeta}{\partial t}=-\frac{\partial S}{\partial x} \quad \cdots\cdots(2')$$

Eliminate ζ from (1') and (2'); there we have

$$\frac{\partial^2 S}{\partial t^2}=gh\frac{\partial^2 S}{\partial x^2}+\frac{\partial T}{\partial t}-k\frac{\partial u}{\partial t}$$

If we assume suitably u as a function of S, we may obtain an approximate solution of S. For instance, when the breadth of a canal is large enough, as u may be put to be proportional to S approximately, the above equation becomes

$$\frac{\partial^2 S}{\partial t^2}+2f\frac{\partial S}{\partial t}=C^2\frac{\partial^2 S}{\partial x^2}+\frac{\partial T}{\partial t} \quad \cdots\cdots(7)$$

where $c^2=gh$ and $2f\dfrac{\partial S}{\partial t}$=the damping term.

This is a foundamental equation of the present problem. For an initially motionless sea, the initial and boundary conditions are as follows;

$S=0$ and $\frac{\partial S}{\partial t}=T$ $\left(\because \frac{\partial \zeta}{\partial x}=0\right)$ where $t=0$ (8), (9).

$S=0$ at the coast $(x=0,\ x=a)$ (10), (11).

Now, if the solution S of eq. (7) satisfying conditions from (8) to (11) can be obtained, substitute it into (2'), then ζ may be obtained by integrating (2') and using the condition that $\zeta=0$ when $t=0$.

Moreover, referring to eq. (1), it must be here noticed that, as long as we use eq. (1), the solution, which satisfies conditions such that the current u is zero on the coasts, cannot generally be obtained, as mentioned in the introduction.

But if we use eq. (7) instead of (1), without considering the current u, we may obtain appropriate solutions matematically and also physically, except for the current in the neighbourhood of the coast.

Thus the coast conditions should be put $S=0$, but not $u=0$ as assumed by many authors.

§ 3. THE SOLUTION OF DIFFERENTIAL EQUATION

(1) The case of constant wind

It will be very complicated to solve directly the general case in which the wind varies with the time, and so the writer, first, attacks the case where the wind action T is costant.

If the case of constant wind is known, he can at once solve also the case of varying wind by Duhamel's theorem. Now when the wind does not vary with the time, eq. (7) may become

$$\frac{\partial^2 S}{\partial t^2}+2f\frac{\partial S}{\partial t}=c^2\frac{\partial^2 S}{\partial x^2} \qquad \cdots\cdots (7')$$

If we may put $\frac{c^2 s^2\pi^2}{a^2}-f^2\geqq 0,$

$$S=\sum_{s=1}^{\infty} B_s\, e^{-ft}\sin\sqrt{\frac{c^2 s^2\pi^2}{a^2}-f^2}\,t\sin\frac{s\pi}{a}x$$

is obviously a solution of (7'), and satisfies the conditions (8), (9), (10). From (9) we have

$$\left|\frac{\partial S}{\partial t}\right|_{t=0}=\sum_{s=1}^{\infty} B_s\sqrt{\frac{c^2 s^2\pi^2}{a^2}-f^2}\sin\frac{s\pi x}{a}=T$$

And we may expand T in Fouriers sine series such as:

$$T=\frac{2}{a}\sum_{s=1}^{\infty}\sin\frac{s\pi x}{a}\int_0^a T\sin\frac{s\pi\lambda}{a}\,d\lambda.$$

Therefore, $$B_s=\frac{2}{a}\frac{1}{\sqrt{\frac{c^2s^2\pi^2}{a^2}-f^2}}\int_0^a T\sin\frac{s\pi\lambda}{a}d\lambda,$$

but since $$\int_0^a T\sin\frac{s\pi\lambda}{a}d\lambda=T\frac{a}{s\pi}(1-\cos s\pi)$$

$$=T\frac{2a}{(2n+1)\pi}\qquad(s=2n+1\,;\text{ odd integer}),$$

$$B_{2n+1}=\frac{4T}{\pi}\sum_{n=0}^{\infty}\frac{1}{2n+1}\frac{1}{\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}}$$

Thus the required total flow S will be given by

$$S=\frac{4}{\pi}\sum_{n=0}^{\infty}\frac{Te^{-ft}}{2n+1}\frac{\sin\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}\,t}{\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}}\sin\frac{(2n+1)\pi x}{a}\qquad\cdots\cdots(12)$$

The eq. (12) is zero at $t=\infty$, and this fact obviously corresponds to the stationary state. Next by substituting the value of (12) in (2′) under the following conditions: $|\zeta|_{t=0}=0$, to determine the value of ζ, we have the following solution of ζ,

$$\zeta=-\frac{4T}{a}\sum_{n=1}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}}\int_0^t e^{-f\tau}\sin\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}\tau d\tau.\qquad\cdots\cdots(13)$$

Then, putting $\sqrt{\frac{c^2(2n+1)^2\pi^2}{a^2}-f^2}=\sigma_n$, we can get ζ as follows:

$$\zeta=-\frac{4T}{a}\sum_{n=0}^{\infty}\frac{1}{f^2+\sigma_n^2}\left\{1-e^{-ft}\left(\frac{f}{\sigma_n}\sin\sigma_nt+\cos\sigma_nt\right)\right\}\cos\frac{(2n+1)\pi x}{a}$$

$$=-\frac{4T}{a}\sum_{n=0}^{\infty}\frac{1}{f^2+\sigma_n^2}\left\{1-\frac{\sqrt{f^2+\sigma_n^2}}{\sigma_n}e^{-ft}\sin(\sigma_nt+\varepsilon)\right\}\cos\frac{(2n+1)\pi x}{a}$$

$$\cdots\cdots(14)$$

This ζ denotes the elevation of the free surface.

And $$\zeta(0,\ t)=-\frac{4T}{a}\sum_{n=0}^{\infty}\frac{1}{f^2+\sigma_n^2}\left\{1-\frac{\sqrt{f^2+\sigma_n^2}}{\sigma_n}e^{-ft}\sin(\sigma_nt+\varepsilon)\right\}$$

$$\zeta(a,\ t)=\frac{4T}{a}\sum_{n=0}^{\infty}\frac{1}{f^2+\sigma_n^2}\left\{1-\frac{\sqrt{f^2+\sigma_n^2}}{\sigma_n}e^{-ft}\sin(\sigma_nt+\varepsilon)\right\}$$

Therefore, $$\zeta(0,\ t)=-\zeta(a,\ t)$$

Namely. the absolute value of the elevation is equal along the both sides of a canal, but the sign of its values is quite oposite.

Moreover, $$\zeta\left(\frac{a}{2},\ t\right)=0$$

Namely, the nodal line of the elevation appears at the center of a canal. Thus, we see that the oscillation of water in a canal generated by wind is antisymmetrical, with respect to the center line of a canal, and this

fact coincides with the result which is already obtained by Prof. K. Hidaka.

Moreover, in the steady state, we have

$$\zeta(x, \infty) = -\frac{4T}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{f^2+\sigma_n^2}$$

(2) The case of varying wind.

From the elevation which should be produced by a constant wind, we can at once derive the formula for the elevation when the wind varies with the time, and let us consider that T is such a function of t that $T=T(t)$.

Indeed by Duhamel's theorem, we can get directly from eq. (14) the elevation required in the present case as:

$$\zeta = -\frac{4}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{f^2+\sigma_n^2}\int_0^t T(\tau)\,\frac{\partial}{\partial t}\left[1-\frac{\sqrt{f^2+\sigma_n^2}}{\sigma_n}e^{-f(t-\tau)}\sin\{\sigma_n(t-\tau)+\varepsilon\}\right]d\tau$$

$$= -\frac{4}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{\sigma_n}\int_0^t T(\tau)\,e^{-f(t-\tau)}\sin\{\sigma_n(t-\tau)\}\,d\tau \quad \cdots\cdots (15)$$

Now, let us consider a simple example of practical importance. Now assume

$T=T_0=$const. for $0<t<t_1$: during the action of the motive force.

$=0$ for $t>t_1$: after the motive force has ceased to act.

When $T=T_0=$const. for $0<t<t_1$, by eq. (14)

$$\zeta = -\frac{4T_0}{a}\sum_{n=0}^{\infty}\frac{1}{f^2+\sigma_n^2}\left\{1-\frac{\sqrt{f^2+\sigma_n^2}}{\sigma_n}e^{-ft}\sin(\sigma_n t+\varepsilon)\right\}\cos\frac{(2n+1)\pi x}{a} \quad \cdots\cdots (16)$$

when $T=0$ for $t>t_1$, by eq. (15)

$$\zeta = -\frac{4}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{\sigma_n}\int_0^{t_1} T_0 e^{-f(t-\tau)}\sin\sigma_n(t-\tau)\,d\tau$$

$$= -\frac{4T_0}{a}\sum_{n=0}^{\infty}\frac{e^{-ft}}{\sigma_n\sqrt{f^2+\sigma_n^2}}\left[e^{ft_1}\sin\{(\sigma_n t+\varepsilon)-\sigma_n t_1\}-\sin(\sigma_n t+\varepsilon)\right]\cos\frac{(2n+1)\pi}{a}x$$

$$= -\frac{4T_0}{a}\sum_{n=0}^{\infty}\frac{\sqrt{2(1-e^{ft_1}\cos\sigma_n t_1)}}{\sigma_n\sqrt{f^2+\sigma_n^2}}e^{-ft}\sin(\sigma_n t+\varepsilon+\delta)\cos\frac{(2n+1)\pi x}{a} \quad \cdots\cdots (17)$$

where $\tan\delta = \dfrac{e^{ft_1}\sin\sigma_n t_1}{1-e^{ft_1}\cos\sigma_n t_1}$

$$\tan\varepsilon = \frac{\sigma_n}{f}$$

In this case, $\left\{eq.\ (16)\right\}_{t\to t_1} = \left\{eq.\ (17)\right\}_{t\to t_1}$, $\zeta(0, t) = -\zeta(a, t)$,

and $\zeta\left(\frac{a}{2}, t\right) = 0.$

The phenomena considered above are found out in the surface fluctuation of Lake Biwa caused by the Muroto Typhoon* on Sept. 21. 1934. In this case, it may be considered that the surface level at Nagahama and Katada approximately corresponds to the $\zeta(0, t)$ and $\zeta(a, t)$, respectively, and the surface level recorded at the time shows that their surface fluctuations coincide with the above value. For reference, the author inserted the wind speed and direction at Hikone at that day.

In Fig. (1), we can see that the amplitude of the surface elevation increased gradualy from 5~6 a.m. on Sept. 21, and the value of elevation extremely increased from 9 a.m., and after 12 a.m. abruptly decreased and there-

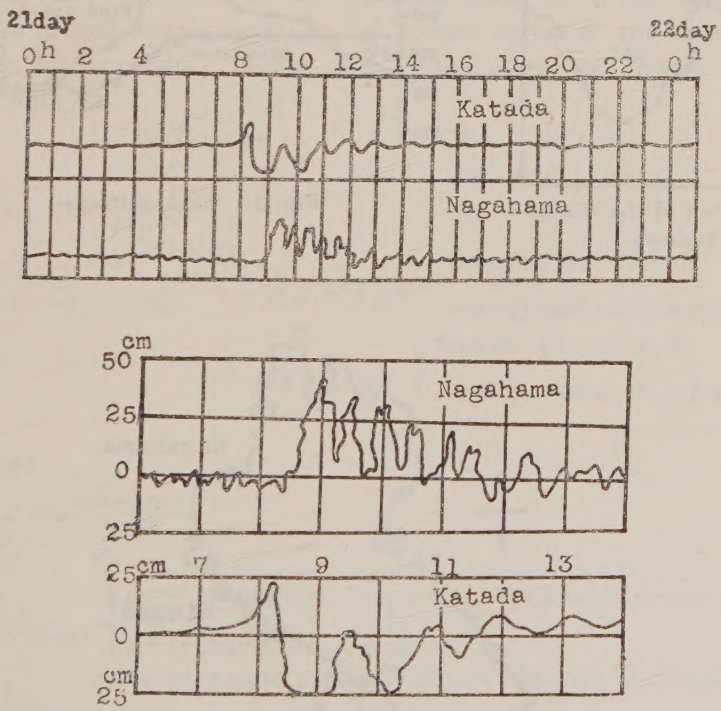

Fig. 1. Level change recorded on Limnogram.

* The typhoon on Sep. 21. 1933, which established a 684 mm world record for deepest central pressure at cape Muroto in Shikoku, passed closed to Lake Biwa between 8.30 a.m. and 9 a.m. as shown in Fig. 2.

The wind and pressure observed at Hikone Meteorogical Observatory, the nearest to the lake, are as shown in Fig. 3.

Then the surface of lake water fluctuated abnormaly, and the oscilletions were obviously recorded on the limnograms at Nagahama, Katada and other stations.

The position of the stations are indicated in Fig. 4, and the limnograms are reproduced in Fig. 1.

after the water surface convergied to the mean level fluctuating up and down.

The wind speed at Hikone showed that it increased gradualy from about 5 a.m., reached the max. speed at 9 a.m., and since then decreased considerably small from about 12 a.m.

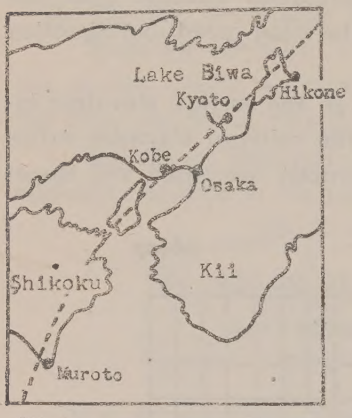

Fig. 2. Path of the Muroto Typhoon.

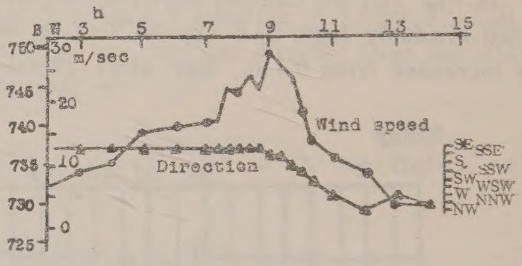

Fig. 3. Wind at Hikone.

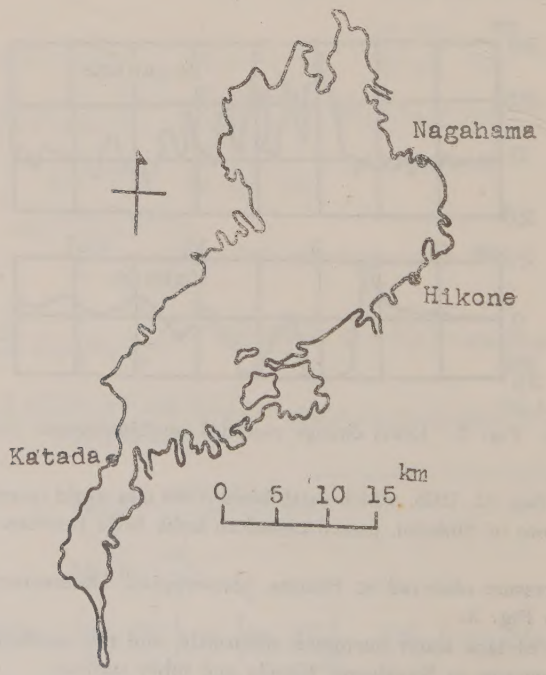

Fig. 4. Lake Biwa and Limnological Stations.

So, if we consider that the above phenomena correspond to $0<t<t_1$ from 5 a.m. to 12 a. m., and $t>t_1$ after 12 a. m., $\zeta(a, t)$ of eq. (16) and (17) correspond to this case. It seemes that the tendency of the curve (sea level) like this case. And, on the other hand, the level at Katada, as shown in Fig. 1, shows the contrary tendency, and this corresponds to $\zeta(0, t)$.

It may be consider that the difference between the time of the beginning of the level change at Katada and Nagahama results from the earlier visitation of Typhoon at Katada.

§ 4. RESONANCE EFFECT.

Eq. (15) includes, of cource, the resonance effect when the motive force varies with a period nearly equal to the proper period of the canal seiche. For example, let us consider here a simple case where the motive is a sine function of time, i.e.

$$T=T_0 \sin pt \qquad \text{for} \quad 0<t<t_1$$
$$=0 \qquad \text{for} \quad t<0, \text{ and } t>t_1$$

Then eq. (15) gives: for $t<t_1$

$$\zeta=-\frac{2T_0}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{\sigma_n}\left[\frac{1}{f^2+(\sigma_n+p)^2}\left\{\begin{array}{l} f\cos pt+(\sigma_n+p)\sin pt \\ -e^{-ft}\{f\cos\sigma_n t-(\sigma_n+p)\sin\sigma_n t\}\end{array}\right\}\right.$$
$$\left.-\frac{1}{f^2+(\sigma_n-p)^2}\left\{\begin{array}{l} f\cos pt-(\sigma_n-p)\sin pt \\ -e^{-ft}\{f\cos\sigma_n t-(\sigma_n-p)\sin\sigma_n t\}\end{array}\right\}\right] \quad \cdots\cdots (18)$$

For $t>t_1$,

$$\zeta=-\frac{2T_0}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{\sigma_n}}{\sigma_n}$$
$$\times\left[\frac{1}{f^2+(\sigma_n+p)^2}\left\{\begin{array}{l} e^{-f(t-t_1)}[f\cos\{\sigma_n t-(\sigma_n+p)t_1\}-(\sigma_n+p)\sin\{\sigma_n t-(\sigma_n+p)t_1\}] \\ e^{-ft}[f\cos\sigma_n t-(\sigma_n+p)\sin\sigma_n t]\end{array}\right\}\right.$$
$$\left.-\frac{1}{f^2+(\sigma_n-p)^2}\left\{\begin{array}{l} e^{-f(t-t_1)}[f\cos\{\sigma_n t-(\sigma_n-p)t_1\}-(\sigma_n-p)\sin\{\sigma_n t-(\sigma_n-p)t_1\}] \\ -e^{-ft}[f\cos\sigma_n t-(\sigma_n-p)\sin\sigma_n t]\end{array}\right\}\right] \quad \cdots\cdots (19)$$

If $f\to 0$ and $t<t_1$, (18) gives

$$\zeta=-\frac{2T_0}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{\sigma_n}\left[\frac{\sin pt+\sin\sigma_n t}{\sigma_n+p}-\frac{\sin\sigma_n t-\sin pt}{\sigma_n-p}\right]$$

which, when $p\to\sigma_n$, become

$$\zeta=-\frac{2T_0}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{p}\left[\frac{\sin pt}{p}-t\cos pt\right] \quad \cdots\cdots (20)$$

For $\infty > t > t_1$, the corresponding formula will be

$$\zeta = -\frac{2T_0}{a}\sum_{n=0}^{\infty}\frac{\cos\frac{(2n+1)\pi x}{a}}{p}\left[\frac{\sin pt_1\cos p(t-t_1)}{2p} - t_1\cos pt\right] \cdots\cdots\cdots\cdots (21)$$

Thus, if t_1 is large, the amplitude will increase greately with time, but when t_1 is small, the amplitude will not be so much enlarged even for a period of perfect resonance.

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